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Achieving Fisheries and Conservation Objectives within Marine Protected Areas: Zoning the Raja Ampat Network

Vera N. Agostini, Hedley S. Grantham, Joanne Wilson, Sangeeta Mangubhai, Chris Rotinsulu, Nur Hidayat, Andreas Muljadi, Muhajir, Meity Mongdong, Arief Darmawan, Lukas Rumetna, Mark V. Erdmann, Hugh P. Possingham

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EXECUTIVE SUMMARY

Raja Ampat is located on the northwestern tip of Papua in eastern Indonesia and lies within the Bird's Head Seascape at the heart of the Coral Triangle. This region comprises 4.5 million hectares of ocean, small islands and coral reefs. Raja Ampat is a national and global priority for conservation as it contains the world's most diverse coral reefs and critical habitats for globally threatened marine species, and is a cetacean migratory corridor. The region's rich coastal and marine resources, a primary source of food and income for local communities, also make it a target for economic development ranging from fisheries and marine tourism to oil and gas extraction, mining and logging. As a result local governments in this region are facing difficult decisions in their attempt to balance sustainable development with conservation of globally significant marine diversity.

Marine conservation and sustainable resource management in Raja Ampat are high priorities for the national, provincial and regency governments. The Raja Ampat MPA network is made up of seven marine protected areas (MPAs) under regency or national jurisdiction which together currently encompass 1,185,940 ha. Management plans for the five regency MPAs will include multiple use zoning plans. This report describes a process conducted to support the development of zoning plans for Raja Ampat's MPA network. Activities undertaken included developing a spatial database on species, habitats and human uses; engaging stakeholders through a series of meeting and workshop; applying state of the art conservation planning tools to synthesize information and examine trade-offs. Key features of this process were:

1) One of the first demonstrations of how to build an information base that can effectively help address multiple management objectives.
2) One of the first demonstrations of simultaneously addressing both conservation and fisheries objectives in a systematic conservation planning platform.
3) A suite of tools that enable practitioners to consider the Raja Ampat MPA network as a whole and visualize the consequences of specific decisions not just for a particular site, but for the network as a whole.
4) A suite of stakeholder consultation activities (including expert mapping exercises and consultation with relevant government agencies and local communities in the region) to ensure that the views and knowledge of local government representatives, practitioners and stakeholders were included in the zoning designs.

Using these tools, it was possible to design a zoning plan which met conservation goals and avoided local fishing grounds by simultaneously considering both objectives. This tool was also used to assess how stakeholder proposed zoning plans met conservation goals or impacted on local fishing grounds.

The suite of products generated are an excellent resource for the provincial and regency government agencies and can help guide coastal and marine planning in Raja Ampat. The products described in this report are integral to any zoning initiative regardless of the scale and number of objectives that are addressed, and can serve as a model for other zoning efforts in Indonesia, the broader Coral Triangle region and other parts of the world.

The process illustrated in this report focused on the Raja Ampat MPA network. As is the case in Raja Ampat, MPAs as networks are usually separated by large distances, and uses in areas outside the MPAs should also be addressed. The work outlined in this report can serve as an important basis for potential future spatial planning activities in the wider Bird's Head Seascape. Management tools such as ocean zoning could facilitate sustainable development at this larger scale providing a number of benefits, including a harmonization with terrestrial land-use planning and tools to facilitate stronger fisheries management that can help secure local community access to food and livelihood in the years to come.

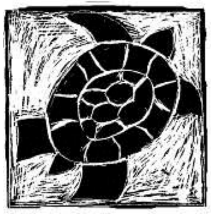

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Photo by: Jeff Yonover

1. INTRODUCTION

1.1 The Coral Triangle – importance and threats

The Coral Triangle is the epicenter of marine diversity and a global priority for marine conservation. The world's most diverse coral reefs occur here, with more than 600 species or 76% of all reefs building coral species recorded in this region (Veron et al. 2009). This region also contains the world's highest diversity of coral reef fish (Allen and Erdmann 2009), seagrass (Short et al. 2007) and mangrove species (Spalding et al. 2010) and supports viable populations of a number of endangered large marine fauna including sea turtles, whales, dolphins and dugongs. The Coral Triangle encompasses all or part of six Indo-Pacific countries including Indonesia, Timor Leste, Papua New Guinea, Solomon Islands, Philippines and Malaysia (Figure 1).

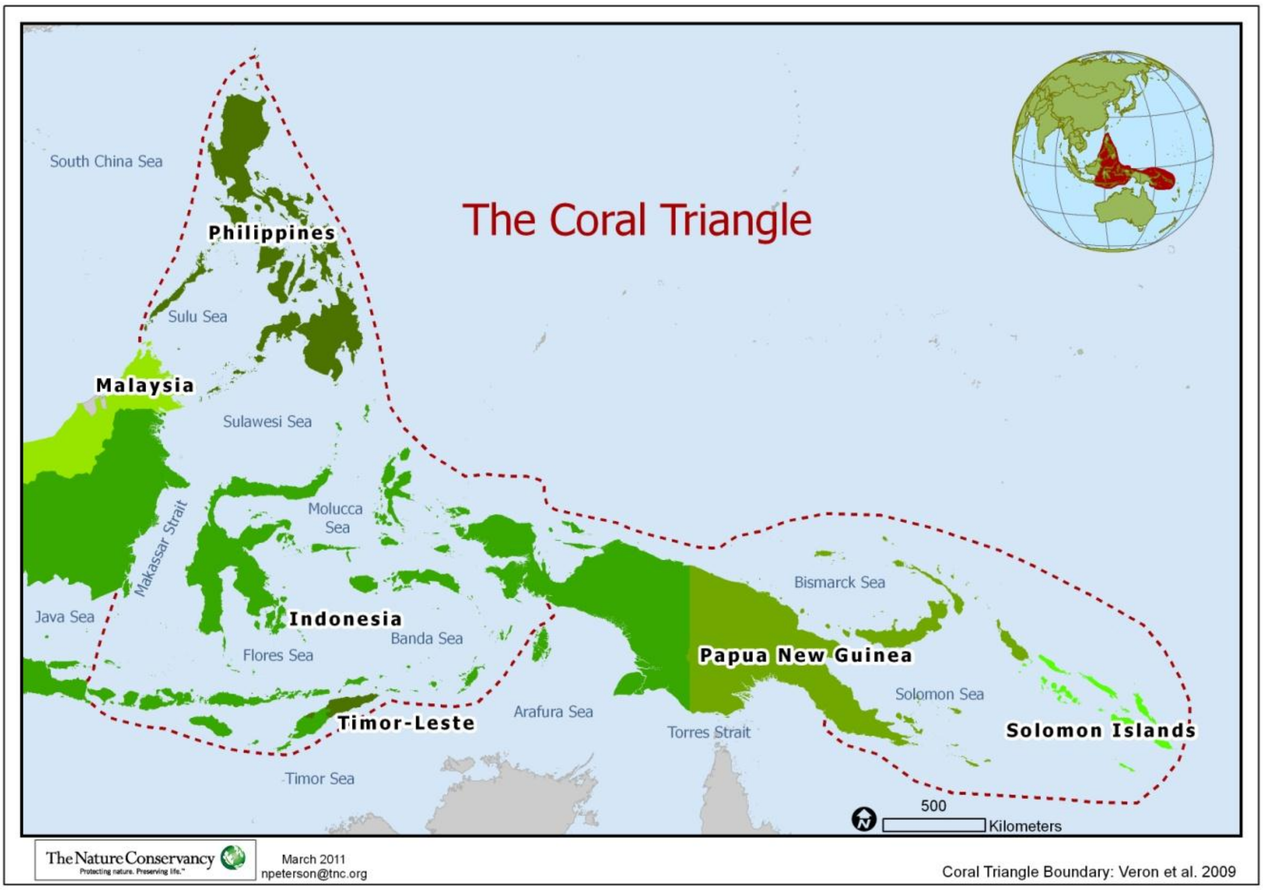


Figure 1. The boundaries of the Coral Triangle

In an archipelagic and developing region such as the Coral Triangle, the importance of healthy coral reefs and shallow coastal habitats for the welfare and livelihoods of local people should not be underestimated. Here, over 100 million people rely directly on coral reefs for their livelihoods

(Hoegh-Guldberg et al. 2009). Coral reefs and associated seagrass and mangrove ecosystems are highly productive “oases” in otherwise oligotrophic or “nutrient poor” tropical waters. This productivity forms the basis for much of the fisheries production which is so important as a source of protein and income for local communities. In addition, these ecosystems provide significant income to local communities from tourism, mariculture and sustainable collection of aquarium fish and coral. Ecosystem services provided by these coastal ecosystems such as coastline protection, sand production and slowing nutrient and sediment loads are also critically important but often undervalued.

Throughout the Coral Triangle, reefs and coastal ecosystems are seriously threatened by overexploitation of marine resources, destructive fishing practices, coastal development, runoff from poor land use practices, and uncontrolled tourism activities (Jackson et al. 2001, Fabric us 2004, Helper et al. 2008, Waycott et al. 2009, Unsworth and Cullen 2010, Burke et al. 2011). A recent review estimated that 95% of reefs in South East Asia and 50% in the Pacific are at risk from these local threats (Burke et al. 2011).

Of all the Coral Triangle countries, Indonesia has the most extensive and diverse coral reefs, but these are also the most threatened. The diversity, frequency and scale of anthropogenic threats have now increased to the extent that many coral reefs have already suffered severe, long-term declines in their diversity, habitat structure and abundance of key species (Pandolfi et al. 2003, 2005, Hughes et al. 2003, Wilkinson 2008, Burke et al. 2011).

In addition to these direct human threats, coral reefs are also threatened by the impacts of climate change (Hoegh-Guldberg et al. 2007). In 1998/1999 and again in 2010, mass coral bleaching associated with elevated sea temperatures during El Niño events affected reefs in many parts of South East Asia including Indonesia (Wilkinson 2008, Tun et al. 2010), Philippines, Malaysia and Thailand. These events which cause bleaching are predicted to increase in frequency and intensity (Hoegh-Guldberg et al. 2009).

1.2 MPAs and MPA networks – addressing threats and providing benefits

Marine Protected Areas (MPAs) are widely accepted as a powerful tool to address threats to coral reefs and protect biodiversity, habitats and ecosystem services (Lubchenco et al. 2003). Arranging multiple MPAs in an ecologically connected “network” can result in increased ecological and fishery benefits (Gaines et al. 2010). Networks of smaller MPAs may be more suitable in areas of high population, high dependence on reef resources for daily food or income, and where submerged lands are under traditional tenure. Ideally an“MPA network” is composed of multiple MPAs that encompass a wide range of coral reef and associated habitat types and species distributions, contain multiple examples of each habitat type, and are spaced within estimated larval dispersal distances to allow for ecological connectivity (McLeod et al. 2009a).

In the Coral Triangle, MPAs are generally managed as either fully protected areas which prohibit any extractive activity including fishing, or as multiple use areas where different types of activities are allowed. In areas of low populations and use, these are usually small and managed by local communities, often under traditional laws. Multiple use MPAs are usually managed by regency or national government agencies and regulate use through a zoning plan which identifies zones for different types of activities. This may include zones for protection, non-extractive use (tourism, conservation, research and education), sustainable extractive use (sustainable fishing, mariculture and other activities) and commercial use. When individual MPAs or MPA networks are effectively managed and zoning systems enforced, many of the “in water” threats to coral reefs such as overfishing, destructive and illegal fishing and poaching, and unregulated coastal development can be significantly reduced.

There are many examples from around the world which show the benefits of MPAs (e.g. McCook et al. 2010, Graham et al. 2011), particularly increases in the diversity, size and abundance of fisheries species within and sometimes outside of MPAs. Other benefits reported include increased herbivory leading to lower macroalgae and increased substrate for coral settlement (Mumby and Harborne 2010), as well as reduced incidence of crown-of-thorns starfish (Sweatman 2008). The Great Barrier Reef is a good example of increased fisheries benefits, where grouper populations increased rapidly in just two to three years in newly created no-take zones (Russ et al. 2008). In Papua New Guinea, there has been some recovery of grouper spawning aggregations after communities agreed to protect relatively small but strategically located protected areas (Hamilton et al. 2011).

The benefits to fisheries from MPAs on coral reefs result from both implementation of no-take areas and increased regulation of fishery practises (reviewed in Graham et al. 2011). Benefits have been reported largely for coastal and coral reef associated species. Numerous studies have shown increases in size and abundance of reef fish within no-take areas where either high levels of compliance (McClanahan et al. 2006) and/or enforcement (Russ et al. 2008, McCook et al. 2010) result in effective no-take zones. Fish which show fastest responses are target fish species, particularly large piscivorous species such as Seranidae (Halpern 2003, Russ et al. 2008) followed by planktivorous species or those that feed on invertebrates (Halpern 2003, Graham et al. 2007) followed in turn by herbivores (Mumby et al. 2006, McClanahan et al. 2007, reviewed in Graham et al. 2011). Populations of directly fished species are more stable inside no-take reserves compared to outside (Babcock et al. 2010). While these increases are due to increased survivorship and growth of fish within areas designated as “no-take”, there is also evidence they are due to behavioral changes in these species, which actively “move” to no-take zones with less boating and fishing activity (Jupiter et al. 2012). While there is mounting evidence that most larvae will recruit back to their home reef

(Almany et al. 2007), some of these larvae are likely to be exported to other areas where fishing is permitted (Gaines et al. 2010), thereby increasing fishery benefits in areas adjacent to no-take zones. Although this theory is logical, few studies provide strong evidence for this. Some studies have shown improved catches immediately adjacent to no-take areas and increases in size and number of high-value species (e.g. Seranidae), which resulted in higher income to local fishers (McClanahan 2010)

1.3 Effective MPA management in the CT

While MPAs are a key strategy for conservation of coral reefs in all six Coral Triangle member countries, achieving effective MPA management remains a challenge. In South East Asia, Burke et al. (2011) estimate only 3% of reefs are effectively managed. In some countries such as Philippines and Solomon Islands, greater success has been achieved through networks of community based MPAs. However in many cases these have not met national goals for conservation. Multiple-use MPAs that accommodate the needs of local communities hold some promise to help achieve effective MPA management. Numerous studies have shown that designing multi-use MPAs by combining both systematic conservation planning and expert/stakeholder input leads to strong outcomes (Game et al. 2011).

1.3.1 Stakeholder input

Stakeholder and expert input can be facilitated at many levels: (a) through expert mapping exercises to document local knowledge on the location of habitats, species and specific uses and activities; (b) by involving local stakeholders/experts in development of objectives and goals; and (c) by soliciting input on the location of zones. Facilitating input from local stakeholders and experts allows for greater awareness, support and ownership of the plan, thereby improving the chance of compliance (Mascia 2001). Compliance with MPA zoning and management plan is critical for the translation of MPA design to conservation or fishery benefits.

In the context of the Coral Triangle, which is characterized by high populations, high reliance on reefs for food and income, and low enforcement, achieving effectively managed MPAs will be dependent on support of local communities and the existence of strong MPA governance systems. It is important to incorporate local environmental knowledge and traditional practices, and to acknowledge existing patterns of use and important fishing grounds in the design of MPA networks or zoning plans for multi-function MPAs.

1.3.2 Systematic MPA design to support multiple uses

Until recently, MPA design has focused on identifying priority areas for conservation with limited consideration of the location of local fishing grounds or other resource use. As MPAs are increasingly being used to fulfill a range of functions, ranging from biodiversity protection to contributing to economic and social welfare (UNEP 2008), MPA design has become a more complex exercise. Managers are realizing that systematic approaches to MPA site selection and design are crucial to deriving maximum benefits (Villa et al. 2002), and a number of tools have been developed to support systematic MPA design.

Tools such as “Marxan” (Ball and Possingham 2000) have been used in some areas of the Coral Triangle to design MPA networks and MPA zoning plans (Green et al. 2009, Wilson et al. 2011). Marxan is a computer-based software program developed to aid in the design of protected areas and protected area networks (Ball and Possingham 2000, Possingham et al. 2000). It was designed to help synthesize and automate the selection process so that many different scenarios for MPA arrangement can be developed and explored. To date these tools have only been able to consider one broad objective – meet all the biodiversity targets for minimum economic impact. They have limited ability to incorporate other factors such as multiple socioeconomic values. A new version of Marxan called “Marxan with Zones” was released in 2009. This tool can identify appropriate areas for different MPA zone types such as conservation and sustainable fishing (Watts et al. 2009). This tool allows users to set socio-economic targets such as: no village will lose more than 20% of their fishing grounds. We anticipate that simultaneously identifying areas important for conservation and for sustainable fishing/resource use may lead to increased compliance and reduced conflict and therefore more effectively managed MPAs.

1.4 Goals of the project

Governance and regulatory systems to support implementation of the Raja Ampat MPA network have recently been established (see Section 2.4 below on governance). These systems specifically treat Raja Ampat as a network and not as a system of separate MPAs. The strong legislative basis for multiple use zoning plans applied at a network scale presented an opportunity to move beyond a focus on individual MPAs and address multiple objectives.

The goal of this project was to provide a set of tools (Decision Support Tools) to support the development of multiple use zoning plans for the Raja Ampat MPA network in West Papua that would help:

1) simultaneously incorporate consideration of conservation values and existing uses. Facilitating multiple uses in MPAs is of utmost importance, given the high reliance of local communities on fishing as a source of food and income, and the importance of developing other sustainable industries such as tourism and mariculture;
2) incorporate the different environmental and resource use characteristics and patterns across Raja Ampat to ensure representation of conservation features across the MPA network, rather than just within individual MPAs.

This report outlines the process we used to develop the Decision Support Tools and concludes with a discussion of how these products can be used to facilitate the ongoing MPA zoning process in Raja Ampat and wider spatial planning processes across Raja Ampat and the Bird's Head Seascape. The sequence of activities we outline here and the tools we developed can serve as an example for other MPA marine zoning efforts around the globe.





Clockwise from top, photos by M. Lazuardi/CI; Aulia Erlangga/CI; Christine Huffard/CI; Sangeeta Mangubhai/TNC; Mark Erdmann/CI

2. RAJA AMPAT

2.1 Location and ecological significance

Raja Ampat is located on the northwestern tip of Papua in eastern Indonesia and lies within the Bird's Head Seascape at the heart of the Coral Triangle (Figure 2).

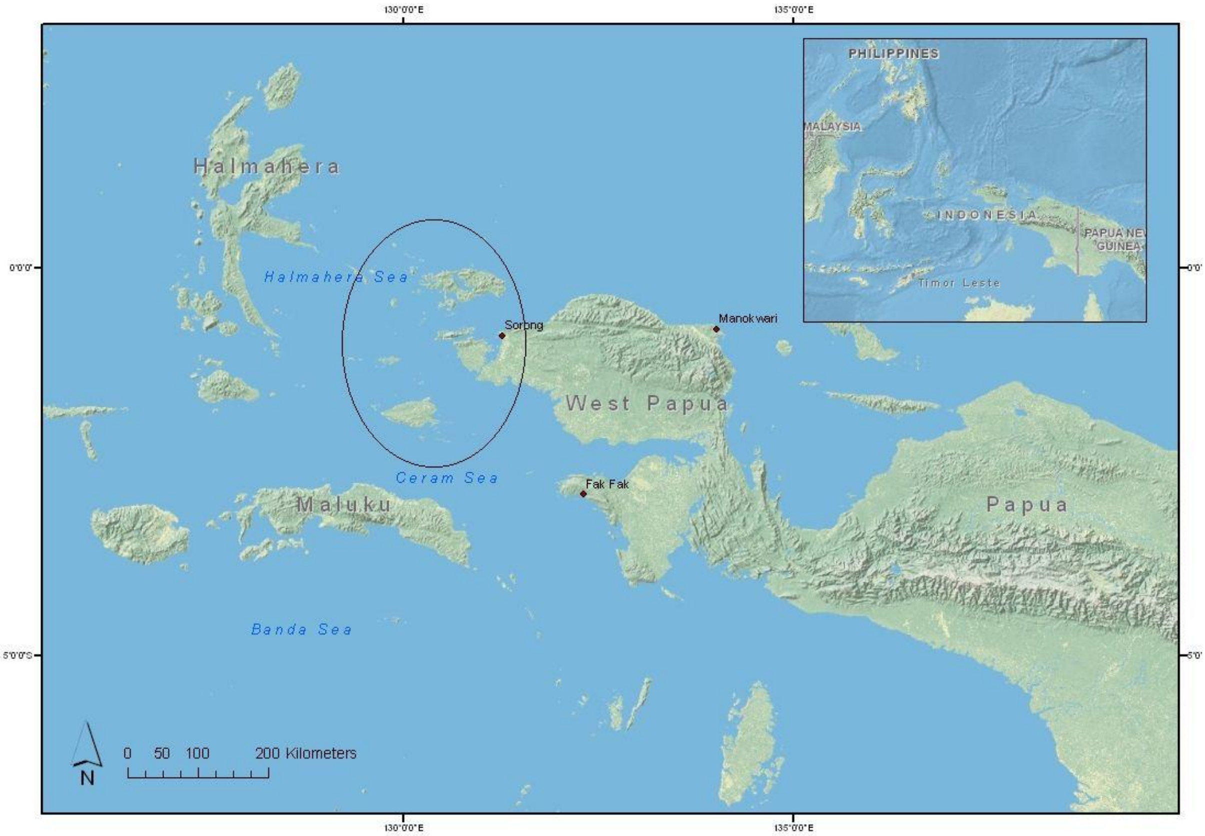


Figure 2. Location of Raja Ampat in the Coral Triangle

This region encompasses 4.5 million hectares of ocean, small islands and coral reefs. Four main islands and hundreds of other small islands are scattered throughout this area (Figure 3).

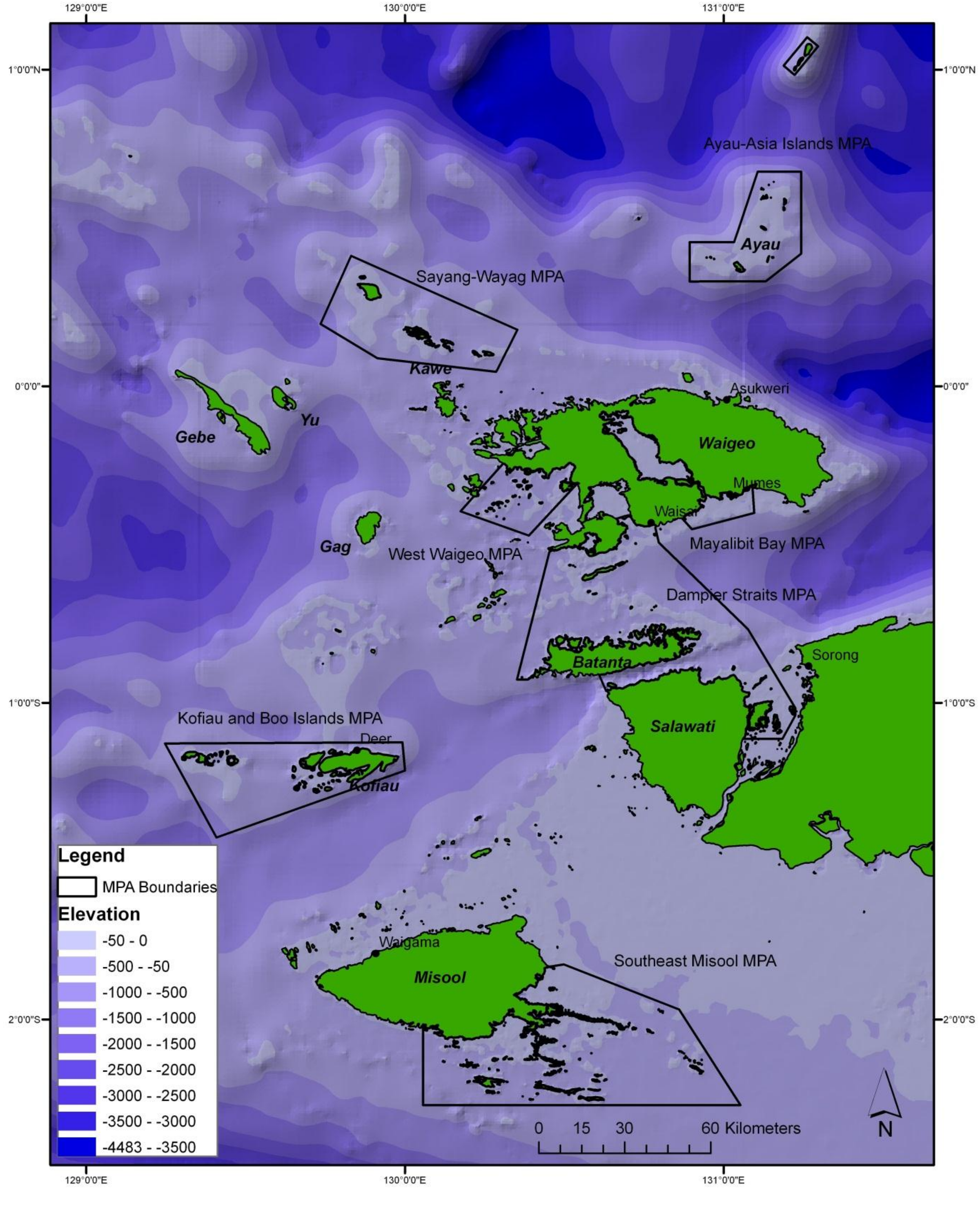


Figure 3. The islands of Raja Ampat and the Raja Ampat Marine Protected Area network

The main islands are generally mountainous and covered in tropical forest, but the area is also famous for its spectacular limestone karst features, which occur in the south and northwest parts of Raja Ampat.

Since the early 1800s, scientific expeditions to Raja Ampat have highlighted the extraordinary marine diversity of this region (Palomares et al. 2007). This high biological diversity across a range of taxa in

Raja Ampat has contributed to identification of the Bird's Head Seascape as a national (Huffard et al. 2009) and global priority for conservation (Roberts 2002). Coral reef surveys in 2001 (McKenna et al. 2002) and 2002 (Donnelly et al. 2003) showed for the first time that the coral reefs of Raja Ampat are the most diverse on the planet. The total number of coral reef fish species recorded is currently 1,427, and 553 species of reef-building coral have been recorded, which accounts for more than 75% of the world's total number of coral species (McKenna et al. 2002, Donnelly et al. 2003, Allen 2007, Allen and Erdmann 2009, Veron et al. 2009, M.V. Erdmann, personal communication). One of the drivers of this extraordinary biodiversity is the high diversity of habitats, ranging from shallow reef habitats which include fringing, barrier, patch and atoll reefs to deep channels between the main islands.

Mangroves and seagrass communities are not extensive but are highly diverse. The number of seagrass species in Raja Ampat has not been determined but Short et al. (2007) note that 12-15 species are recorded in this region. Scientific surveys have recorded 25 mangrove species in Raja Ampat (Firman and Azhar 2006). "Blue water" mangrove stands growing in clear water next to well-developed coral reefs occur in some areas and are a popular location for divers (Jones and Shimlock 2009).

Raja Ampat is also an important area for large marine fauna including nesting and foraging populations of turtles, such as green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) (Donnelly et al. 2003). In addition, a total of 17 species of marine mammals have been recorded, including nine whale species, seven dolphin species, and dugong (*Dugong dugon*) (Kahn 2007, Muljadi 2009, Syakir and Lantang 2009). Raja Ampat is likely to be an important migratory pathway and a feeding and breeding ground for these species.

Raja Ampat encompasses numerous deep sea features such as seamounts, pinnacles and undersea canyons which are very important habitat for cetaceans, fish and some specialized deep-sea fauna. In addition, perched saltwater lakes occur throughout Raja Ampat and contain endemic species of sponge or unusual species adaptations such as the stingless jellyfish (Becking et al. 2011).

2.2 Oceanography

Oceanographic patterns in Raja Ampat are complex, as this region sits at the nexus of the Pacific and Indian Oceans. Broadscale current patterns are generated by the passage of the "Indonesian Throughflow" from the Pacific Ocean in a north-south direction through the archipelago and a strong clockwise eddy to the west (the Halmahera eddy) of Raja Ampat. The passage of strong currents through the myriad of small islands and reefs creates local eddies and turbulence resulting in good connectivity among reefs (Barber et al. 2002).

There are two distinct seasonal influences on Raja Ampat – the southeast monsoon from May-October and the northwest monsoon from November-March. Sea surface temperatures in Raja Ampat generally follow seasonal patterns of warmer sea temperatures (around 30°C) in the Austral summer (December – February), with waters cooling in winter (June – August) to 26.5°C at the onset of the southern monsoon. Data from temperature loggers througout Raja Ampat, deployed from 2005-2010, show that the average sea surface temperature in Raja Ampat was 29.0°C, with temperatures ranging from 19.3–36.0°C. Short term temperature variability is high at some sites due to cold-water upwelling or super heating and cooling in shallow lagoons and temperatures can vary by up to 13°C over a 24-hour period (G. Purba and M. V. Erdmann, unpublished data). Reef flats can also experience similar diurnal and tidal fluctuations in temperature regimes.

2.3 Culture/historical context

Raja Ampat has a rich and diverse cultural heritage that includes indigenous Melanesians, long-time settlers from surrounding parts of Indonesia, and from as far away as the Middle East due to the spice trade era (Donnelly et al. 2003, Palomares et al. 2007). Most of the people that live in Raja Ampat Islands belong to the Raja Ampat ethnic group, which consists of two major Tribes – Maya and Matbat – and at least 17 smaller tribes. Maya Tribes occupies the northern part of Raja Ampat Islands covering Waigeo, Salawati and several small surrounding islands. Matbat Tribes generally occupies the southern Raja Ampat Islands: Misool and small surrounding islands (TNC 2004). Also government-initiated transmigration of people, particularly from Java (Timmer 2007) has introduced a number of additional tribes (e.g. Bugis, Buton, Maluku). Religion has a very strong influence, and numerous village enclaves of Christians and Muslims are scattered throughout the entire archipelago. Raja Ampat's isolation and fairly low population until now have made it possible for its coral reefs and other habitats to stay in fairly good condition relative to the rest of Indonesia (Pauly and Martosubroto 1996, Donnelly et al. 2003).

2.4 Governance and tenure

Indonesia has a three-tiered system of government at national, provincial and local (regency or district) levels. The Raja Ampat Regency was created in 2003 and lies within the West Papua Province. Regency governments hold the authority and responsibility for natural resource management including the declaration of MPAs within their boundaries.

In addition to the national, provincial and district governance systems, there is a complex customary system in West Papua, which includes a system of traditional tenure over both land and marine areas. Practices of traditional natural marine resource management (*sasi*) are still in place in many areas and include restrictions on harvesting certain species at particular times and locations (McLeod et al. 2009b).

2.5 Natural resource use

Local communities are highly dependent on natural resources for their food and income. Socioeconomic surveys have shown that most Raja Ampat residents live in small remote villages close to the coast and practice both farming and fishing to provide food for their families (TNC 2004, Larsen et al. 2011). The importance of marine resources to local communities is indicated by the strong tenurial system and traditional management practices over marine resources.

Increasingly, marine resources of Raja Ampat are exploited for commercial gain both legally and illegally (Palomares et al. 2007), although often the latter is undertaken by “outsiders” (i.e. people from outside the region) (Bailey et al. 2008, Varkey et al. 2010). Marine resource use includes subsistence fisheries, commercial fisheries, mariculture (pearl culture and seaweed farming), dive tourism, oil and gas extraction, and commercial shipping.

Fishing is one of the most important sources of food and income for local communities. Small-scale commercial and subsistence fishing is important for most village livelihoods (TNC 2004). Fish are caught using a variety of fishing gear, with hand line, gleaning and trolling the most common (TNC 2004, Muljadi 2009, Syakir and Lantang 2009, Larsen et al. 2011, Conservation International, unpublished data). Fish targeted include both reef fish – particularly wrasse, grouper, snapper, parrotfish and surgeonfish – and pelagic fish – e.g. sardine, anchovy, skipjack tuna and Spanish mackerel (McKenna et al. 2002, Donnelly et al. 2003, TNC 2004). Sea-cucumbers and shellfish such as *Trochus* and green snail (*Turbo marmoratus*) are also commercially important species for local communities (Varkey et al. 2010).

Large-scale commercial fishing activities include bagan or lift net fishing (Bailey et al. 2008), long lining, tuna fishing, shark finning, and the live reef fish food trade (Wilson et al. 2010), but exclude trawling, which is banned in most Indonesian waters. Fish stocks appear to decline (Palomares et al. 2007, Ainsworth et al. 2008), and there are ongoing significant issues with illegal, unreported and unregulated fisheries (Varkey et al. 2010).

Recently, land-based activities have affected the marine and coastal areas in Raja Ampat. Poorly regulated mining, forestry and coastal development activities in Raja Ampat are causing runoff of sediment and nutrients into sensitive coastal waters, leading to loss of seagrass beds and fringing coral reefs as well as declining water quality in several areas, notably around southern Waigeo (Conservation International, unpublished data).

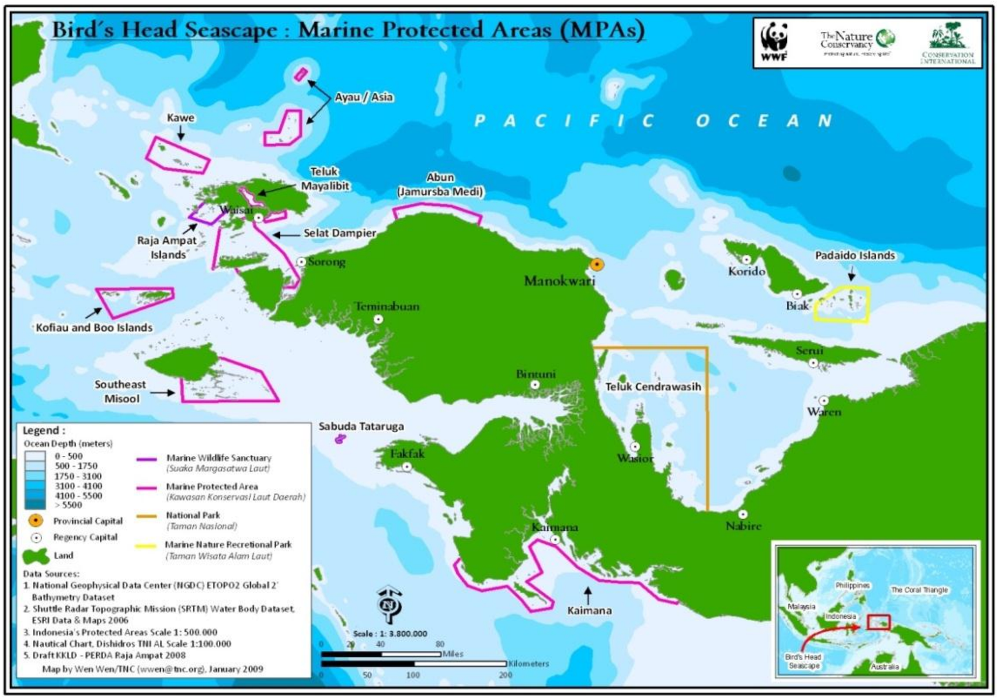
2.6 Challenges and opportunities for conservation and sustainable use

In Raja Ampat, there are many enabling conditions for conservation and sustainable natural resource use, but also significant challenges. On the one hand, strong community support exists for sustainable use which benefits local communities and for a growing economy based on fishing, tourism and mariculture which relies on ecosystem health. On the other, illegal and destructive fishing, forestry and mining still occur, population in coastal areas is rapidly expanding due to transmigration, and government policy supports accelerated development to aleviate poverty.

While this region still faces significant challenges to conservation of both marine and forest ecosystems, there are encouraging indications that the value of sustainable natural resource management is being recognised by natioinal and Raja Ampat governments. The national government has designated Raja Ampat Regency as a "national strategy area" for marine conservation which is recognized in provincial spatial plans. Another important step was the declaration of the Raja Ampat MPA network by the Raja Ampat Regency in 2007.

2.7 MPA Network

The Raja Ampat Regency government created the Raja Ampat MPA network through the declaration of six MPAs in 2007, encompassing 835,210 ha (Figure 3). Prior to 2007, only one MPA existed in Raja Ampat (60,000 ha), located in Southwest Waigeo and managed by the National Department of Forestry and Conservation. Management of this MPA and one of the MPAs declared by the Raja Ampat Regency (Kawe) were recently given national-level status by the Ministry for Marine Affairs and Fisheries. In 2009, the boundaries of three of the MPAs (Mayalibit Bay, Dampier Strait and Southeast Misool) were expanded through a head-of-government decree (*Peraturan Bupati* No.5/2009), and the seven MPAs in the Raja Ampat network now cover a total of 1,185,940 ha. The Raja Ampat MPA network is part of a larger network across the Bird's Head Seascape which includes 12 MPAs encompassing more than 3 million ha (Figure 4).



` **Figure 4**. The Bird's Head Seascape Marine Protected Area network

The MPA network is governed by the Raja Ampat Regency and the Ministry of Marine Affairs and Fisheries (MMAF) with support from The Nature Conservancy (TNC), Conservation International (CI) and the COREMAP program. The size of, and management institution for, each MPA is given in Table 1.

Table 1. Size and management institution for each MPA in the Raja Ampat MPA network

MPA	Size (ha)	Management
Ayau / Asia	101 440	Raja Ampat Regency
Kawe	155 000	Ministry of Marine Affairs and Fisheries
Raja Ampat	60 000	Ministry of Marine Affairs and Fisheries
Mayalibit Bay	53 000	Raja Ampat Regency
Dampier Strait	303 200	Raja Ampat Regency
Kofiau	170 000	Raja Ampat Regency
SE Misool	343 200	Raja Ampat Regency

Governance and regulatory frameworks to support implementation of the five MPAs administered by the Raja Ampat Regency have recently been established under Law 27/2007. Under this legislation, MPAs are managed for multiple uses through a management plan which includes zoning plans for each of the MPAs.

In Raja Ampat, this will be applied at the network scale which means MPAs will be managed as a network instead of a system of separate MPAs and managed by a single management unit under the Marine and Fisheries Agency (Rumetna et al. 2010). The Raja Ampat government is currently developing management and zoning plans for five of the seven MPAs in the MPA network with support from TNC and CI. Draft management plans have been produced MPAs in the network that have national recognition, and zoning plans are close to completion for MPAs managed by the regency.


SCUBAPRO

Photos by: Dwi Aryo Handono/TNC, Sally Kailola/TNC, Jeff Yonover

3. DEVELOPING TOOLS TO SUPPORT ZONING

In order to support the zoning of Raja Ampat's MPA network, we focused our activities around five essential elements. These elements should provide the foundation of any MPA zoning effort:

i) establishing clear objectives;
ii) building a multi-objective database;
iii) synthesizing information and examining tradeoffs;
iv) engaging stakeholders; and
v) generating tools.

3.1 Establishing clear objectives

Effective marine zoning needs to be guided by clear objectives and a strategic vision developed with local practitioners and stakeholders (Beck et al. 2009, Agostini et al. 2010). As recommended by IUCN (2008), we considered three broad categories of objectives: ecological, economic and sociocultural. In addition to protecting important habitat and species (ecological objectives) we considered how the region will benefit from the network and how local economic needs (e.g. fisheries and mariculture) could integrate with national and regency sustainable development goals (economic objectives). Finally, we carefully considered how the MPA network should contribute to the livelihood and food needs of the local community (sociocultural objectives). From these broad-scale regional objectives we developed operational objectives ("goals") that would be relevant at each site (Table 2).

Table 2. Operational objectives (goals) developed for each zone

Zone	Target	Goal
No-take	MPA Network Coral Reef Classes	30%
	Misool Coral Reef Classes	30%
	Mangroves	30%
	Seagrass	30%
	Ayau manta nursery	30%
	Ayau grouper and Napoleon reef fish nursery	30%
	Kawe shark and manta nursery	30%
	Kofiau and Boo Islands and Misool turtle nesting beaches	75%
	Northern turtle nesting beaches	75%
	Blue Spot Stingray spawning aggregation	75%
	Coral reef fish spawning aggregation	100%
	Misool potential coral reef fish spawning aggregation	50%
	Kofiau and Boo Islands potential coral reef fish spawning aggregation	50%
	Manta aggregation sites	75%
	Frigate Nesting	75%
	Tern Nesting	75%
	Leather back jellyfish feeding area	75%
	Dugong hotspots	50%
	Coconut crab	75%
	Sawfish	75%
	Guitar shark	75%
	Whale shark	75%
	Sharks	50%
	Dolphin	30%
	Whale	30%
	Manta	30%
	Dugong	30%
	White Dolphin	50%
	Crocodiles	50%
Sustainable Fishing	Individual community fishing grounds	75%

This was done in consultation with local practitioners and based on guidance provided by the existing Raja Ampat MPA network design criteria (Table 3).

Table 3a. Biophysical Marine Protected Area design criteria.

Design criteria	Application
Risk Spreading (representation and replication)	• Conserve a minimum of 20% with a goal of 30% of shallow coastal habitats (coral reefs, mangroves, seagrass and estuaries) and, where possible, include all habitat classifications (e.g. coral reef types) in no-take zones. • Include a minimum of three replicates of each habitat types in no-take zones distributed over a large area to reduce the chance all would be impacted by the same disturbance event. • Each no-take zone should be a minimum of 10-20km diameter where possible. • No-take zones should be simple shapes to minimize edge effects while maximizing the protected area.
Connectivity within and among MPAs	• Where possible include areas that contain multiple habitat types (coral reefs, mangroves, estuaries and seagrass) in no-take zones to maintain connectivity among habitats. • Aim for no-take zones within MPAs to be spaced no more than 15km apart to maintain ecological connectivity. • Avoid fragmentation by including entire biological or geomorphic units (e.g. whole reefs, seamounts, lagoons) in no-take zones. • Where possible choose no-take zones in areas adjacent to terrestrial reserves, to maximize coastal ecosystem integrity.
Protecting Key Sites and Species	Include critical or unique sites such as: • habitat of threatened or protected species, e.g. crocodiles, turtles • areas with very high diversity, high levels of endemism or unique marine communities, • areas that support important key life history stages such as fish spawning aggregations, shark aggregation or breeding sites, turtle nesting beaches and feeding/resting areas and seabird nesting sites, • cetacean aggregation areas and migratory corridors and dugong feeding habitat, and • important pelagic habitat areas, e.g. areas of upwelling, fronts, eddies.
Designing for Resilience to Climate Change	Incorporate sites that are likely to be be resilient to global climate change. Areas that may be resilient to climate change-induced bleaching events include: • areas that regularly experience high temperature variability, including periods of high temperatures, e.g. lagoons • areas that experience upwelling and strong currents, • areas that are shaded by coastal vegetation or cliffs, • areas with good herbivorous fish communities, and • areas with good coral recruitment. Areas that may be resilient to climate change induced sea level rise impacts include: • mangrove areas that have room to expand their range inland • turtle nesting beaches that have room to expand their range inland.

Table 3b. Socio-economic Marine Protected Area design criteria

Design criteria	Application
Benefits to people	• Allow for multiple activities, including sustainable fishing, tourism, aquaculture, education and research. • Minimize negative impacts on existing livelihood strategies and maximize opportunities for alternative incomes. • Cost-benefits from marine protected areas are fairly and equitably distributed between communities. • Minimize conflicting uses (e.g. tourism versus fisheries).
Cultural	• Recognize and respect the Papuan marine tenure system and local communities' rights, by ensuring local resource owners are central in decision-making process. • Incorporate traditional knowledge and traditional conservation and sustainable fisheries practices into marine protected area management. • Protect areas of cultural-traditional importance to local resource owners.
Fisheries	• Support subsistence fishing needs and low-impact fisheries. • Ensure development of marine protected areas that are designed to support subsistence and non-destructive and sustainable artisanal fisheries for local communities. • Facilitate and support the implementation of management practices that support sustainable, low-impact commercial fisheries. • Take into consideration species that are important for community fisheries (e.g. Trochus, sea cucumber, lobster, green snail, abalone, giant clams), and recognize their spatial and temporal variations in resource use and values • Consider fished species vulnerable to over-exploitation (e.g. groupers, sharks).
Sustainable development	• Protect high potential tourism sites. • Support low-impact environmentally friendly industries that are compatible with marine protected areas (e.g. ecotourism, pearl farm) . • Avoid placing marine protected areas or no-take zones in the vicinity of existing shipping infrastructure.

The network design criteria took into account important biophysical and sociocultural and economic characteristics of the region as well as resilience principles of MPA network design (McLeod et al. 2009a). Many of these criteria have been applied to MPA and to MPA network design in other areas of the Coral Triangle, including Papua New Guinea (Green et al. 2009), Palau (Hinchley et al. 2007), and the Lesser Sunda Ecoregion in Indonesia (Wilson et al. 2011).

3.2 Building a multi-objective database

A comprehensive spatial database is a central piece of any planning process, whether this leads to an MPA, a zoning plan, or both, as it helps us understand current management and guide future management. As the focus was on multiple uses, we needed to collect disparate types of information (e.g., habitat and species types, existing human uses and threats to conservation/sustainable use) across the MPA network. In order to do this, a variety of potential sources of information were evaluated and efforts were made to collate, update and generate appropriate spatial datasets.

3.2.1 Design

We categorized information into three themes: habitats, species, human uses and threats (Table 4). Our intention was to develop a database that would allow us to assign equal value and weight to human uses and conservation. By not simply classifying the data from the perspective of conservation (e.g. assigning fisheries as a threat or "cost"), we created a multi-objective database and provided partners, stakeholders and decision makers in the regional strong basis for future multi-objective planning.

3.2.2 Information layers

We identified an ideal list of datasets in each of the three themes above and identified all existing sources of information for each. As many of the existing datasets were at a coarse scale, covered only a small area of Raja Ampat, or were potentially out of date, datasets were augmented with Geographic Information System (GIS) layers generated from expert mapping, expert analysis of existing datasets, and some additional data collection and ground truthing. Methods of data collection for each category are provided in Table 4.

Table 4. Sources of spatial information

Target class	Target	Data Sources	Method
Habitats	MPA Network Coral Reef Classification	De Vantier et al. (2009)	Based on oceanography, bathymetry and physico-chemical parameters, habitats, coral communities, reef fishes and expert opinion to define these classes
	Misool Coral Reef Classification	The Nature Conservancy	Surveys collected data on the reef communities, exposure and slopes to verify and adjust the classification system proposed by De Vantier et al. (2009)
	Coral Reef Extent	Raja Ampat Atlas, The Nature Conservancy and Conservation International	Field mapping/remote sensing
	Coral Reef Condition	The Nature Conservancy and Conservation International	Manta tow surveys
	Lagoon	Raja Ampat Atlas, The Nature Conservancy	Field surveys/remote sensing
	Seagrass	Expert mapping, The Nature Conservancy and Conservation International	Field surveys/remote sensing
	Mangroves	Raja Ampat Atlas, The Nature Conservancy	Field surveys/remote sensing
	Ayau manta nursery	Workshop	Expert mapping
	Ayau grouper and Napoleon reef fish nursery	Workshop	Expert mapping
	Kawe shark and manta nursery	Workshop	Expert mapping
	Kofiau and Boo Islands and Misool turtle nesting beaches	The Nature Conservancy	Surveys and local information
	Northern turtle nesting beaches	WWF Indonesia, Conservation International	Surveys and local information
	Blue Spot Stingray spawning aggregation	Workshop	Expert mapping

	Coral reef fish spawning aggregation	Workshop	Expert mapping
	Misool potential coral reef fish spawning aggregation	The Nature Conservancy, Rhodes 2008	Surveys of fishermen and underwater surveys
Species	Kofiau and Boo Islands potential coral reef fish spawning aggregation	The Nature Conservancy, Rhodes 2008	Surveys of fishermen and underwater surveys
	Ayau fish spawning aggregation	Workshop	Expert mapping
	Manta aggregation sites	Workshop	Expert mapping
	Frigate Nesting	Workshop	Expert mapping
	Tern Nesting	Workshop	Expert mapping
	Leatherback jellyfish feeding area	Workshop	Expert mapping
	Dugong hotspots	The Nature Conservancy Field Team, Conservation International	Combined information on seagrass, survey data and expert data
	Coconut crab	The Nature Conservancy, Conservation International	Expert mapping
	Sawfish	Workshop	Expert mapping
	Guitar shark	Workshop	Expert mapping
	Whale shark	Workshop	Expert mapping
	Dolphin	Workshop, The Nature Conservancy, Conservation International	Estimated from various survey sources and expert mapping
	Whale	Workshop, The Nature Conservancy, Conservation International	Estimated from various survey sources and expert mapping

	Manta	Workshop	Expert mapping
	Dugong	Workshop, The Nature Conservancy, Conservation International	Estimated from various survey sources and expert mapping
	White Dolphin	Workshop	Expert mapping
	Sharks	The Nature Conservancy, Conservation International	Outline of the around reef in Ayau where there were many records from the aerial survey and a 1km buffer around other points
	Crocodiles	Workshop	Expert mapping
Human uses	Individual community fishing grounds	Workshop, The Nature Conservancy, Conservation International	Expert mapping
	Fishing Shelter	The Nature Conservancy and Conservation International	Aerial surveys and boat based surveys
	Fishing Cage	The Nature Conservancy and Conservation International	Aerial surveys and boat based surveys
	Fishing FAD	The Nature Conservancy and Conservation International	Aerial surveys and boat based surveys
	Fishing Sero	The Nature Conservancy and Conservation International	Aerial surveys and boat based surveys
	Seaweed and Pearl farming	Workshop, The Nature Conservancy, Conservation International	Combined expert mapping with field based surveys
Threats	Sediment plumes	Workshop, The Nature Conservancy, Conservation International	Remote sensing, expert mapping

Base information

We obtained datasets of key physical features such as coastlines, eco regions, national, provincial and regency boundaries, MPA boundaries, bathymetry (marine), and coastal topography (terrestrial) from relevant government departments in Indonesia including the Ministry of Forestry and Nature Conservation, the Ministry of Marine Affairs and Fisheries, the Department of Mapping and the Department of Planning.

Habitats

Shallow coastal habitats were defined as all marine-influenced habitats including estuaries, mangrove, seagrass, lagoons, coral reef and seamounts. The distribution of some of these features was obtained from the files used to generate the Raja Ampat Atlas (Firman and Azhir 2006). Prior to this study no information was available on the classification of habitats in Raja Ampat. While there was not enough information to classify seagrass and mangrove habitats, we commissioned a classification of coral reef habitats (DeVantier et al. 2009). The authors used site-specific field data from previous studies, expert opinion, reef maps and atlases, aerial photography, and satellite imagery to delineate fourteen coral reef seascapes based on geomorphology, community composition and exposure (DeVantier et al. 2009). Additional information was obtained from monitoring and field studies of coral reefs, and expert mapping (see Section 3.3).

Species

The distribution of species and critcal habitat such as nesting beaches, spawning aggregations and migration corridors were gathered from sighting records, results of monitoring programs, dedicated surveys, published reports and expert mapping. In many cases available data were point values which needed to be converted to areas in order to obtain the necessary spatial information for the analysis. This was done by examining the distribution of the point based records and combining it with information on key habitats. For example, we determined an area of likely distribution of dugongs by examining both the distribution of sightings and the known areas of seagrass distribution.

Human uses

Data on a range of human activities including artisanal and commercial fishing, mariculture, shipping, mining, oil and gas extraction, tourism, traditional *sasi* areas, permanent and temporary structures such as fish traps, fishing huts and seawalls were collected and documented in the GIS database. Data sources included observations of the location and type of activity or vessel from ongoing resource use monitoring within MPAs and previous aerial surveys. However most information on the location and type of human uses was obtained through participatory expert mapping (see Section 3.3).

Threats

Information on sediment runoff was also included, as this poses a significant threat to conservation. We mapped the location of sediment plumes via expert mapping and by setting a 2km buffer around the end of rivers which had mining or significant clearing in the catchment, on the assumption that this would be an important source of erosion and sedimentation.

3.3 Synthesizing information and examining tradeoffs

In order to integrate a wide variety of information and explore tradeoffs between placing fisheries and conservation zones in specific areas, we used Marxan with Zones (see Section 3.5). Marxan with Zones requires a variety of specific data input, including:

1. A spatial unit for the analysis ("planning unit")
2. The current status of each planning unit
3. A list of zone types
4. Spatial information on "features" and a list of associated quantitative "targets" that relate to each zone
5. A metric that summarizes factors to avoid ("cost") for each zone type
6. Parameters to guide appropriate location of zones

The following is a description of how each of these elements were defined for this project.

3.3.1 A spatial unit for the analysis (i.e. planning units)

The project area was defined by the boundary of the Raja Ampat Regency, which contains seven MPAs (Figure 5).

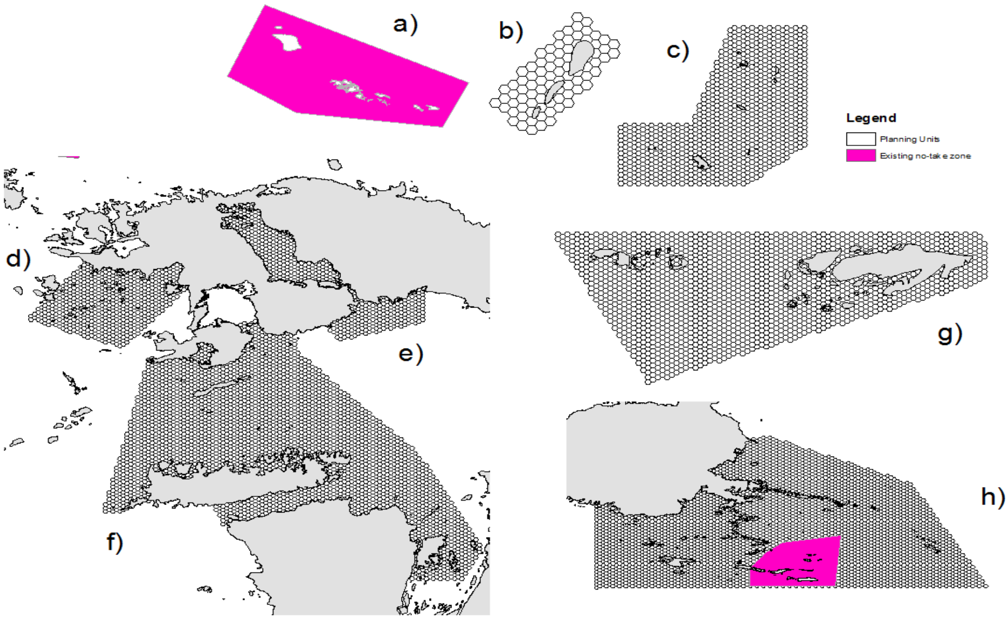


Figure 5. Map of study area and planning units. a) Sayang-Wayang MPA, b) Ayau-Asia MPA northern section, c) Ayau-Asia MPA south section, d), West Waigeo MPA, e) Mayalibit Bay MPA, f) Dampier Strait MPA, g) Kofiau and Boo Islands MPA and h) Southeast Misool MPA. Please note that the MPAs represented are not at scale.

Marxan with Zones requires that the area of focus be divided into "planning units" so that each characteristic and activity for the area in question contained in the project database can be summarized into planning units. Planning units are a pre-defined suite of areas, typically hexagons, that house all the necessary information required for a Marxan with Zones analysis. These units permit the program to run and allow comparison and selection between potential zoning areas. Planning units must capture all the areas that can possibly be selected as part of the zoning design, and their size should be at a scale appropriate to the information available. In general, planning units should be no smaller than the features mapped and no larger than is realistic for management decisions. That is, the planning units should be smaller than the smallest area allocated to a particular zone. Other considerations include the number of planning units – depending on computing power, if planning units are too small then it takes a long time to run each scenario. Each of the seven MPAs in the Raja Ampat MPA network were divided into 1km^2 hexagon shaped planning units, giving a total of 11,480 planning units (Figure 5).

3.3.2 The status of each planning unit

Marxan with Zones requires definition of the current management status of a planning unit. This indicates if managers have already allocated the planning unit to a zone, thus making it unavailable for selection for any other kind of zone within the analysis.

3.3.3 Zone types

For a Marxan with Zones analysis, the number and type of zones should be defined. Ideally the number of zones should be limited and determined in consultation with practitioners and/or stakeholders. At the time of this analysis, legal regulations for, and names of, MPA zones were not available for the Raja Ampat MPA network. However, through discussions with stakeholders and examination of existing MPA regulations elsewhere in Indonesia, two types of zones were identified as the highest priorities for Raja Ampat MPA network –"no-take" and "sustainable fisheries". We acknowledge that these are not the same names as will appear when the zoning regulations are released, but they can be applied to appropriate future zones. No-take zones are primarily a fisheries management tool and in Indonesia allow for non-extractive activities such as education, research and tourism, while sustainable fishing areas allow for sustainable extractive activities including non-destructive fisheries, mariculture and tourism.

3.3.4 Spatial information on "targets" and a list of associated quantitative "goals"

Marxan with Zones allocates areas (planning units) to no-take and sustainable fishing zones based on goals. The software allows for both zone specific goals, for example the representation of a percentage of the area of the distribution of "targets" (sometimes referred to as "features") in each zone. In this analysis for no-take zones, targets were conservation features such as habitats and species distribution; for sustainable fishing zones, targets were local fishing grounds. Therefore, information in the geodatabase on habitats, species and resource use were used as inputs for the analysis. The goal or percent representation assigned to each target was guided by the zoning design criteria outlined in Table 2, the extent and distribution of each target, and the importance or rarity of the target.

3.3.5 A metric that summarizes factors to avoid ("cost")

Marxan with Zones also uses a"cost layer" in the analysis to influence how it selects areas to be assigned to each zone. A cost layer incorporates factors which may compromise the value of the zone or make it difficult for that zone to be implemented in a specific area. For example, for a no-take zone, cost factors include pre-existing extractive uses such as mariculture which are not permitted in no-take zones. Marxan with Zones will try to minimize cost while simultaneously trying to choose areas which meet representation goals for targets for each zone type.

For no-take zones the total cost of each planning unit C_{NT}, is:

$C_{NT} = r + m + f + c + s + 100$

where *r* is a measure of reef condition (% dead coral + % dead rubble), *m* is the occurrence of mariculture (seaweed farming + pearl farming / 2), *f* is the occurrence of fishing structures (FADs + fishing cages + fishing shelters + fixed fish traps) as presence or absence, *c* is a measure of the cost of a site in terms of its use for community fishing grounds (sum of all fishing grounds / 127 (the total number of fishing grounds) and *s* is the occurrence of a sediment plume.

The cost for the sustainable fishing zone, $C_{SF,}$ was based on only one factor – the distance to the nearest village (d).

$C_{SF} = d$

Therefore a fishing ground further away from a local village had a higher cost than those closer to the village because fishing grounds closer to villages are easier to access. Further, because the way in which we combined the costs was subjective, changing the relative importance of different costs is worthwhile to see the consequences of different management scenarios.

3.3.6 Parameters to guide appropriate location of zones (zone boundary cost)

To meet the goals for representation of each target, zones can be allocated across many small or a few large areas. The degree of “fragmentation” will influence the effectiveness and difficulty of implementation of the zones. Too much fragmentation results in a design characterized by many small areas which may not be large enough to protect a habitat or species or act as a productive fishing ground; in addition the location of boundaries may be confusing to stakeholders and difficult to manage. Allocating no take zones to just a few large areas may make it difficult to achieve replication goals and may cause conflict with resource users. In Marxan with Zones, exploring the impact of varying levels of fragmentation is achieved by calibrating a parameter representing compactness (zone boundary cost). The zone boundary cost can also function to encourage further separation of conflicting uses or to cluster zones which share compatible management objectives. This can be useful when trying to minimize the potential conflict between activities taking place in different zones such as conservation and fishing (Watts et al. 2009). Optimal parameters for spatial compactness and buffering of zones were derived through a calibration process described in the Marxan with Zones User Guide (Watts et al. 2008).

3.4 Engaging stakeholders

Engaging local community, government representatives and conservation practitioners (herein termed stakeholders) was a high priority in this project. It allowed us to fill important gaps in existing information, incorporate important local expert knowledge, effectively address needs on the ground and facilitate support for the zoning process. Stakeholder engagement activities included:

- community partipatory mapping – local communities identified local fishing grounds and preferred areas for conservation zones in each MPA;
- expert mapping – local government agency representatives and MPA practitioners documented the location of conservation targets, threats and priority areas for conservation and fishing; and
- feedback on zoning plan design – local communities, local government agency representatives and MPA practitioners provided inputs on draft zoning plan designs.

Stakeholder engagement was facilitated through formal and informal meetings and through two expert workshops held at various stages throughout the project. During these meetings and workshops, existing information was supplemented with new information, current information was verified, and analysis outputs were reviewed. In addition, these workshops supported engagement of partners and stakeholders in the zoning process and facilitated a network view of zoning efforts for those undertaking zoning activities at each MPA site.

3.4.1 Community participatory mapping

At each MPA, local field teams worked with key informants in each village to map the location of fishing grounds used by each community. This was done in small groups, with participants identifying fishing ground boundaries which were then drawn by hand on large printouts of maps for that region/MPA. Fishing grounds were identified by target species and by the village which had ownership or use rights. The maps and additional data collected were digitized and incorporated into the GIS database as polygons and metadata.

3.4.2 Expert mapping

As some of the existing datasets for Raja Ampat were at a coarse scale or covered only a small area of Raja Ampat, or were potentially out of date, participatory expert mapping with stakeholders was used to update, complement or complete key datasets. During this project we held a number of formal and informal expert mapping activities which engaged stakeholders, government and NGO staff in the region. This provided an opportunity to rapidly improve a common understanding of the region as well as create an informal network to identify and share information.

Most of the expert mapping was done during the first stakeholder workshop held February 16-17, 2009, in Sorong, West Papua. Over 20 representatives from CI/TNC/WWF field teams, local government agencies (Department of Fisheries and Marine Affairs, Department of Forestry, and Department of Environment) and local NGOs participated in the workshop (Appendix 1a). At the beginning of the workshop we provided participants with the context of the project and offered an overview of existing data. We then explained how information from expert mapping would be used to improve existing data and contribute to MPA zoning. For example, we showed how a community proposal of a zoning configuration can help inform final zone placement. The participants were then divided into several groups based on the location and scale of their work. For example, many participants work within an individual MPA and were thus assigned to an MPA focused group; others, such as government staff, work across the MPA network and were thus able to provide information at a regency scale.

During the workshop we asked participants to share information they had or were aware of, including GIS layers, GPS points, spreadsheets, spatial plans, reports and relevant studies. We then asked participants to draw on maps to help fill in data gaps, and we provided guidelines on documenting these data by listing the types of datasets that were needed. This included fisheries (e.g. shark finning locations, fishing grounds), human uses and threats (e.g. ports, dive sites, mariculture), oceanography (e.g. primary productivity, fronts, currents), and the distribution of habitats and species (e.g. seagrass, turtle nesting beaches, fish spawning sites). Some additional information was obtained at a second stakeholder workshop in February 2010 (Section 3.4.3).This information was digitized and geo-referenced and included in the geodatabase. Selected datasets were also used in the zoning analysis.

3.4.3 Feedback on zoning design

A second stakeholder workshop was held in Sorong, West Papua in February 9-10, 2010, with similar participants as the first stakeholder workshop (Appendix 1b). The objective of this workshop was to present the results of preliminary analysis and seek feedback on the location of candidate areas for no-take and sustainable fishing zones and complete the expert mapping to finalize maps of habitats, species and human uses. During this workshop, MPA practitioners also provided information from recent meetings with local communities on their preferred location of no-take and fishing zones. These areas were identified on maps and extensive notes were taken on the reasons why these areas were chosen for each zone type. This new information was then included in the database and final Marxan with zones analysis.

3.5 Generating tools to help support MPA zoning decisions

One of the most important aspects of a successful zoning process is having access to and integrating complex information. Helping stakeholders access a set of tools ("Decision Support Tools") able to effectively package, synthesize and analyze a wide variety of information is integral to an effective planning process. Decision Support Tools provide transparency in decision making and a mechanism to engage a diverse range of stakeholders in the planning process; they can capture, share, and compare many people's ideas about planning options; help people understand the real-world implications of different management regimes and environmental conditions; and reveal tradeoffs among possible management scenarios (Beck et al. 2009). Below we discuss the tools we developed for Raja Ampat and provide guidance on how this can be used to support zoning decisions for the network.

3.5.1 Habitat, Species, Uses and Threat maps

The spatial information collected during this project was organized and managed in an Environmental Systems Research Institute (ESRI) geodatabase format. The geodatabase allows for centralized data storage for easy access and management and a range of sophisticated spatial analyses, and it can be used in larger planning processes. In addition, all spatial information was also stored and made available in ESRI's ArcView 3x shapefile, which is a more universal format. The geodatabase and each shapefile include information about how and when these data were created and/or collected (i.e. metadata). The majority of these files have been made available to partners in the region.

3.5.2 Zoning analysis

In order to assess the impact of different decisions on the future location of no-take zones and sustainable fishing zones, we explored three scenarios in Marxan with Zones:

Scenario 1: Addressing multiple objectives: simultaneously identifying potential areas for conservation and fisheries zones which achieve goals for both protection of conservation features and access to fishing grounds;

Scenario 2: Addressing a single objective – conservation: identifying potential areas for conservation zones which achieve goals for protection of conservation features only; and

Scenario 3: Incorporating community preferences: simultaneously identifying potential areas for conservation and fisheries zones which also incorporate community preferences for areas designated for conservation and fishing in each MPA.

All of these scenarios were explored across the network, rather than on a site-by-site basis. The outputs from these scenarios help identify areas of high conservation and high fishing values and are designed to assist decision makers as they consider variations in zoning designs. We viewed these scenarios as central to addressing some of the existing discussions around zoning of the MPAs, such as "how do we effectively integrate community knowledge and information from our field based monitoring programs in a systematic planning effort?", or "how do we effectively address important fisher needs and not sacrifice biodiversity protection goals?" In the results section below, we outline main results by scenario. For additional details on this analysis, including a full set of maps generated, please see Grantham and Possingham (2010) and Grantham et al. (2012).

The Marxan with Zones analysis produced a series of results that help highlight the location of important fisheries and conservation areas (Figures 8-10) as well as help summarize what percent of analysis "features" and "targets" are captured by these areas (Figures 6-7, 14-15). For information on how to use these tables and figures to inform zoning decisions, please see Section 3.5.3.

3.5.2.1 Scenario 1 – Addressing multiple objectives

For this scenario we were able to find zoning configurations that achieved nearly all goals for both the sustainable fishing and no-take zones (Figures 6 and 7). Figures 8-10 illustrate the location of areas that are important for fisheries and areas that are important for conservation, Figure 8 shows combined information on how frequently a planning unit has been selected for either no-take or sustainable fishing zone and Figures 9 and 10 representing this information for either no-take (Figure 9) or sustainable fishing (Figure 10) zones. Areas in dark green are the ones likely to be the most important to include in a future no-take area (Figures 8 and 9), areas in dark blue are ones likely to be most important to include in future sustainable fishing zones (Figures 8 and 10), areas in white are ones that were not assigned to either zone type and thus flexible (i.e. could be assigned to either).

When one considers the distribution of candidate areas to include in each zone, the following overall patterns emerge. The Kofiau and Boo Islands MPA was selected mostly for sustainable fishing areas. The northern area of the main section of Ayau-Asia MPA was frequently selected for inclusion as a no-take zone. There were four main areas of the Dampier Strait MPA that were frequently selected for the no-take zone: the first was in the northern coastal area of the MPA; the second was off the north-western side of Batanta Island; the third was on the south-east coastal area of Batanta Island; the last area was in the far south eastern section of the MPA. Areas that were frequently selected for the no-take zone in Mayalibit Bay were concentrated in the north-eastern area of the MPA. Fishing and conservation areas are more clearly defined in Ayau-Asia, Dampier Strait, West Waigeo and Mayalibit Bay compared to fishing and no-take areas in Southeast Misool and Kofiau and Boo Islands, where they were more fragmented. One of the reasons may be that important fishing grounds are located adjacent to important no-take areas in the southern MPAs (Southeast Misool and Kofiau and Boo Islands) compared to the northern MPAs (Ayau-Asia, Dampier Strait, West Waigeo and Mayalibit Bay) in Raja Ampat. Another reason may be the difference in level of information on fisheries and community use between the northern and southern MPAs, with the southern MPAs having more community data available.

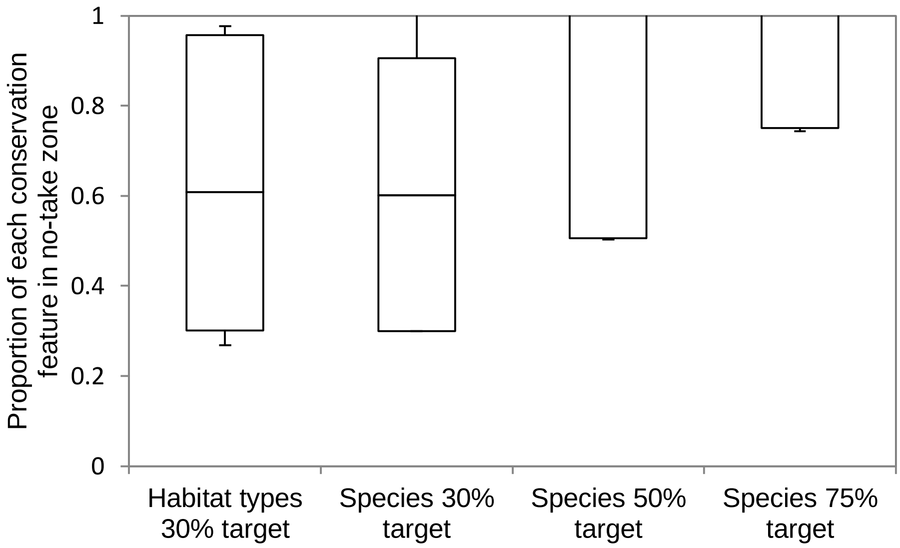


Figure 6. The proportion of each no-take zone target summed by species and habitats captured by the areas selected in the best solution as no-take zones. All habitat targets had a 30% goal. For species, there were three different goals used. The boxplot shows the range, upper and lower quartiles and median values.

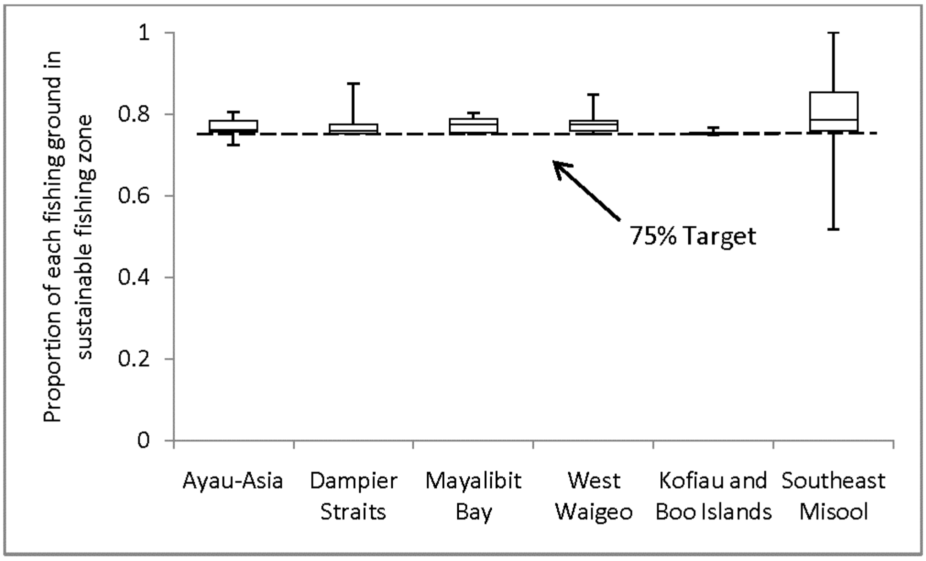


Figure 7. The proportion of each fishing ground at each Raja Ampat Marine Protected Area captured by the areas selected in the best solution as sustainable fishing zones. The boxplot shows the range, upper and lower quartiles and median values.

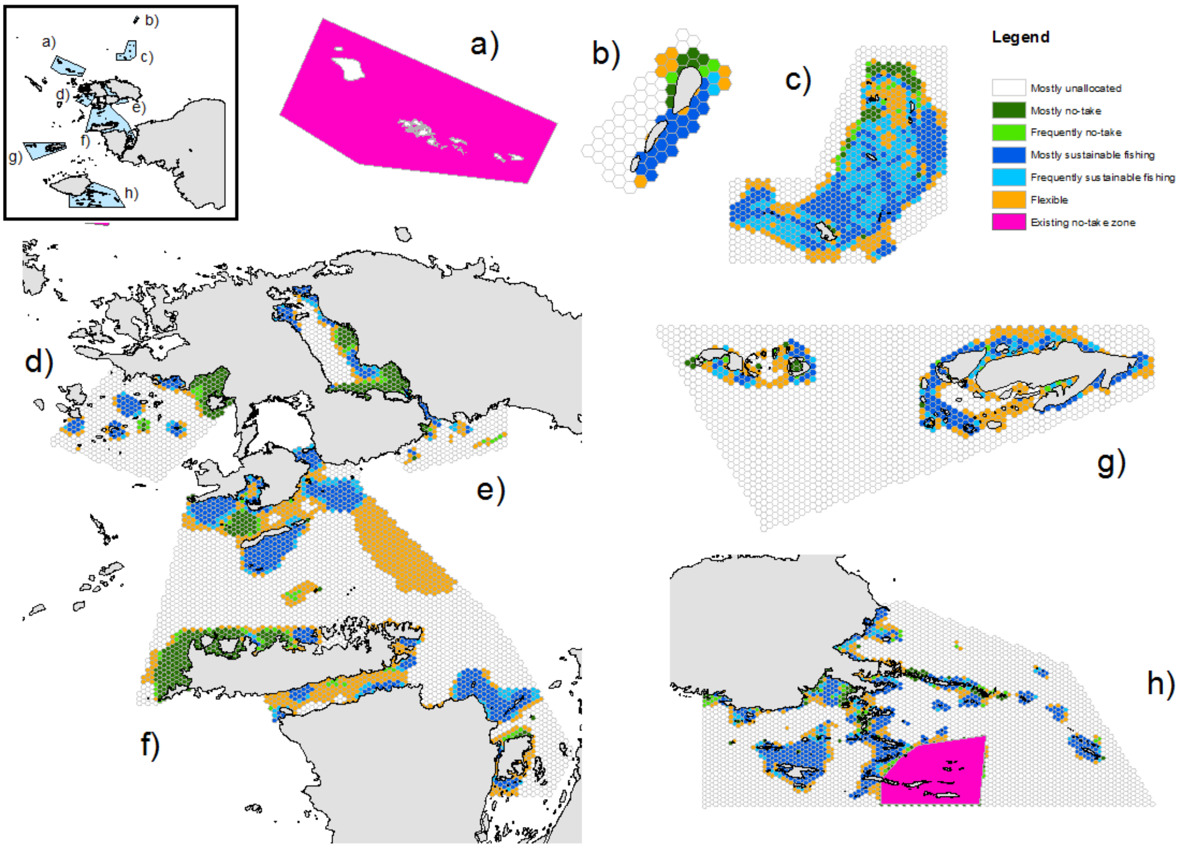


Figure 8. Candidate no-take and sustainable fishing areas for scenario 1 (classified solution maps). Each planning unit is classified according to the proportion of times the planning unit was selected for a specific zone as follows: "mostly no-take" (selection frequency = 80-100% for no-take zone), "frequently no-take" (selection frequency 60-79% for no-take zone), "mostly sustainable fishing" (selection frequency = 60-100% for sustainable fishing zone), "frequently sustainable fishing" (selection frequency 60-79% for sustainable fishing zone), "mostly unallocated" (selection frequency = 60-100% for unallocated zone), and "flexible" (the rest of the planning units selected). a) Sayang-Wayang MPA, b) Ayau-Asia MPA northern section, c) Ayau-Asia MPA south section, d), West Waigeo MPA, e) Mayalibit Bay MPA, f) Dampier Strait MPA, g) Kofiau and Boo Islands MPA and h) Southeast Misool MPA. Please note that the MPAs represented are not at scale.

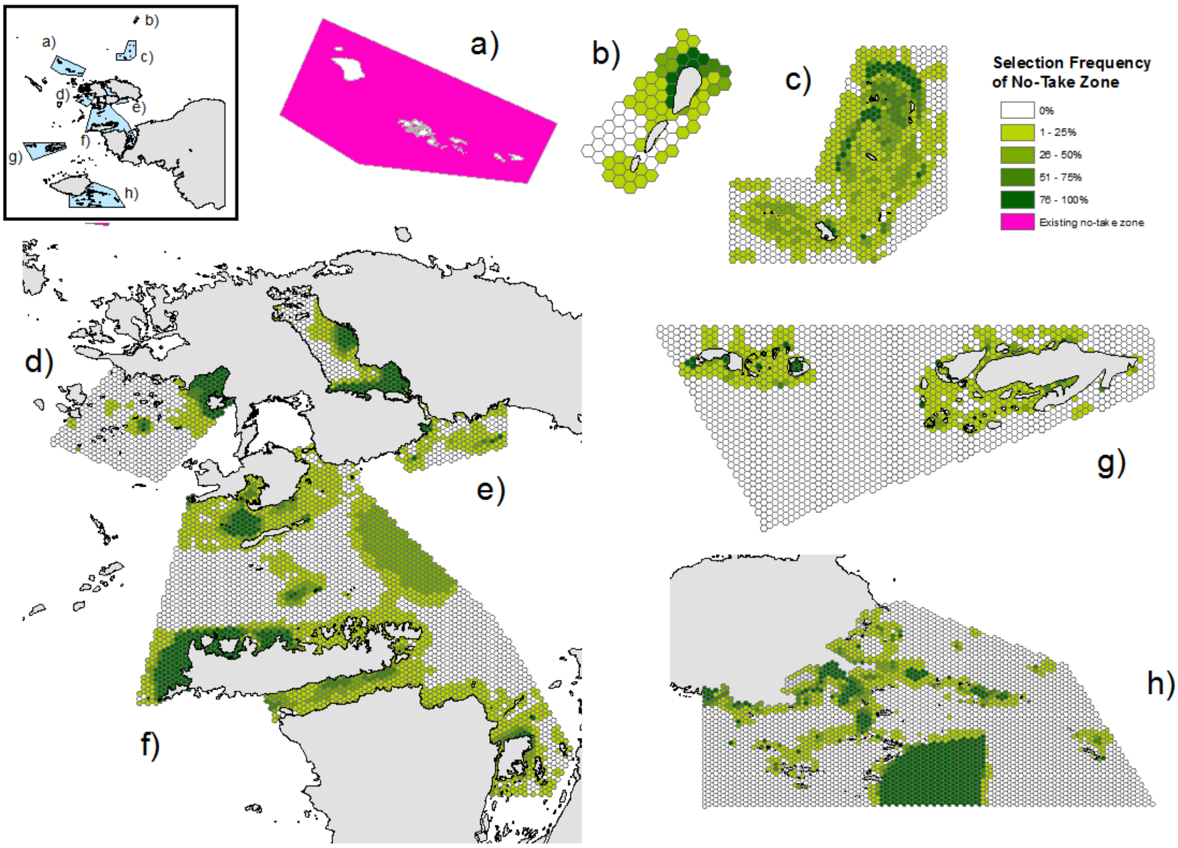


Figure 9. Candidate conservation areas for scenario 1 (selection frequency maps). Each planning unit is classified according to the frequency or number of time it was selected to be in a no-take zone. a) Sayang-Wayang MPA, b) Ayau-Asia MPA northern section, c) Ayau-Asia MPA south section, d), West Waigeo MPA, e) Mayalibit Bay MPA, f) Dampier Strait MPA, g) Kofiau and Boo Islands MPA and h) Southeast Misool MPA. Please note that the MPAs represented are not at scale.

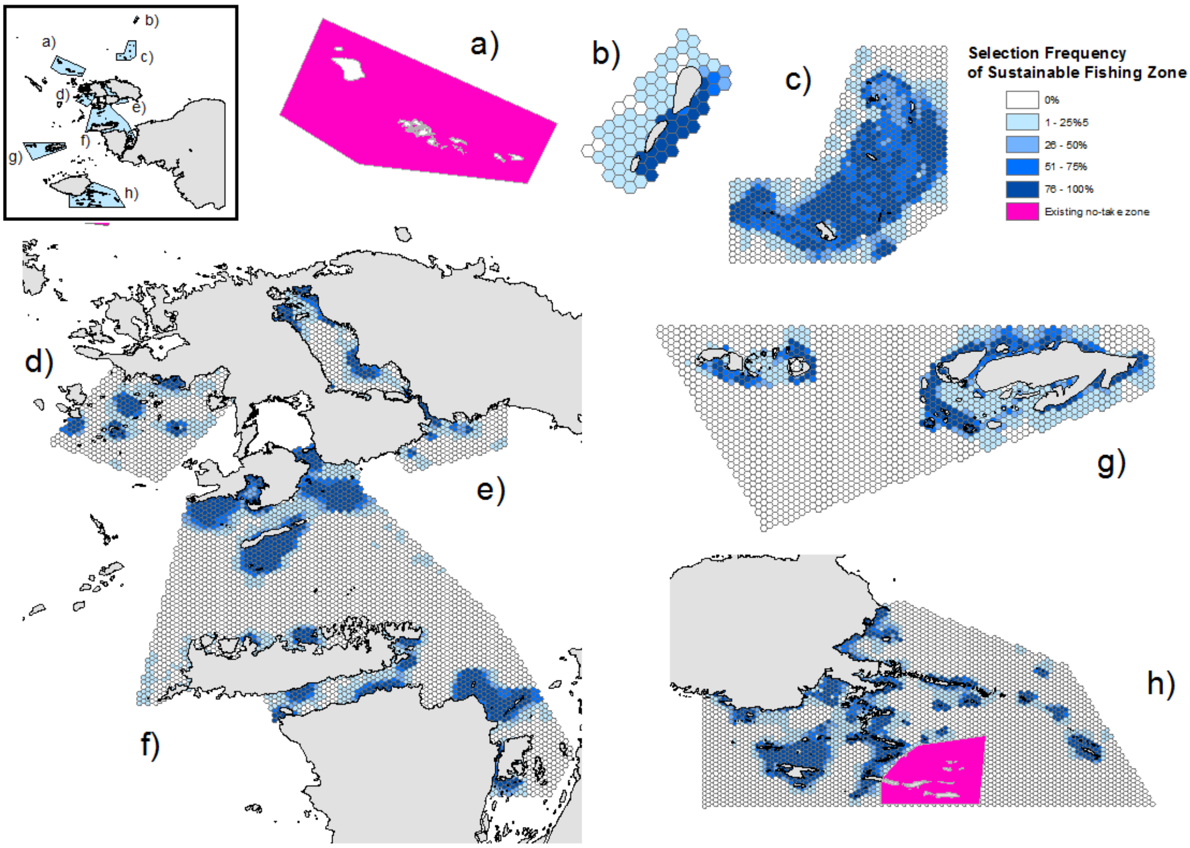


Figure 10. Candidate sustainable fishing areas for scenario 1 (selection frequency maps). Each planning unit is classified according to the frequency or number of times it was selected to be in a sustainable fishing zone. a) Sayang-Wayang MPA, b) Ayau-Asia MPA northern section, c) Ayau-Asia MPA south section, d), West Waigeo MPA, e) Mayalibit Bay MPA, f) Dampier Strait MPA, g) Kofiau and Boo Islands MPA and h) Southeast Misool MPA. Please note that the MPAs represented are not at scale.

3.5.2.2 Scenario 2 – only addressing conservation objectives

In this scenario, we identified potential areas for no-take zones based only on the distribution of conservation targets and minimising the "cost" (this is similar to what is typically done in a Marxan analysis). We ran this scenario to examine any differences between addressing multiple objectives (conservation and fisheries) versus a single objective (conservation) in the location or size of the no-take zones and the impact on fishing grounds. There was little difference between Scenario 1 and 2 in the location and size of the no-take zones, with conservation goals achieved in both scenarios. We found the differences in the location of no-take zones to be generally small and mainly located in the northeast of West Waigeo MPA, the western part of Dampier Strait MPA, Boo Island on the western part of Kofiau and Boo Islands MPA and various locations throughout Southeast Misool MPA (Figure 11). However, there was a significant impact on the access to fishing grounds (Figure 12).

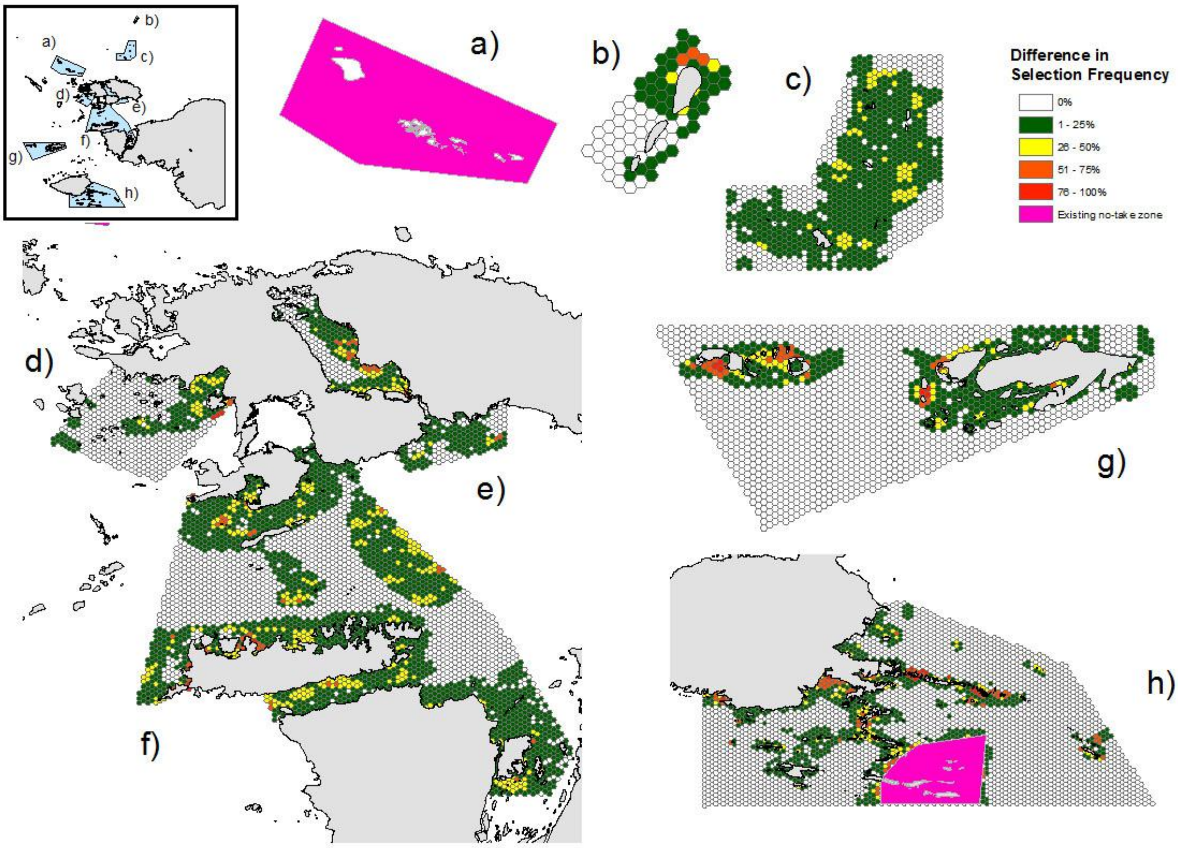


Figure 11. Map showing the difference of no-take zone goals achieved in scenario one and two. Represents the percentage difference in the selection frequencies for no-take zone between scenarios one (identifying locations for both zones) and two (identifying locations for one zone). a) Sayang-Wayang MPA, b) Ayau-Asia MPA northern section, c) Ayau-Asia MPA south section, d), West Waigeo MPA, e) Mayalibit Bay MPA, f) Dampier Strait MPA, g) Kofiau and Boo Islands MPA and h) Southeast Misool MPA.

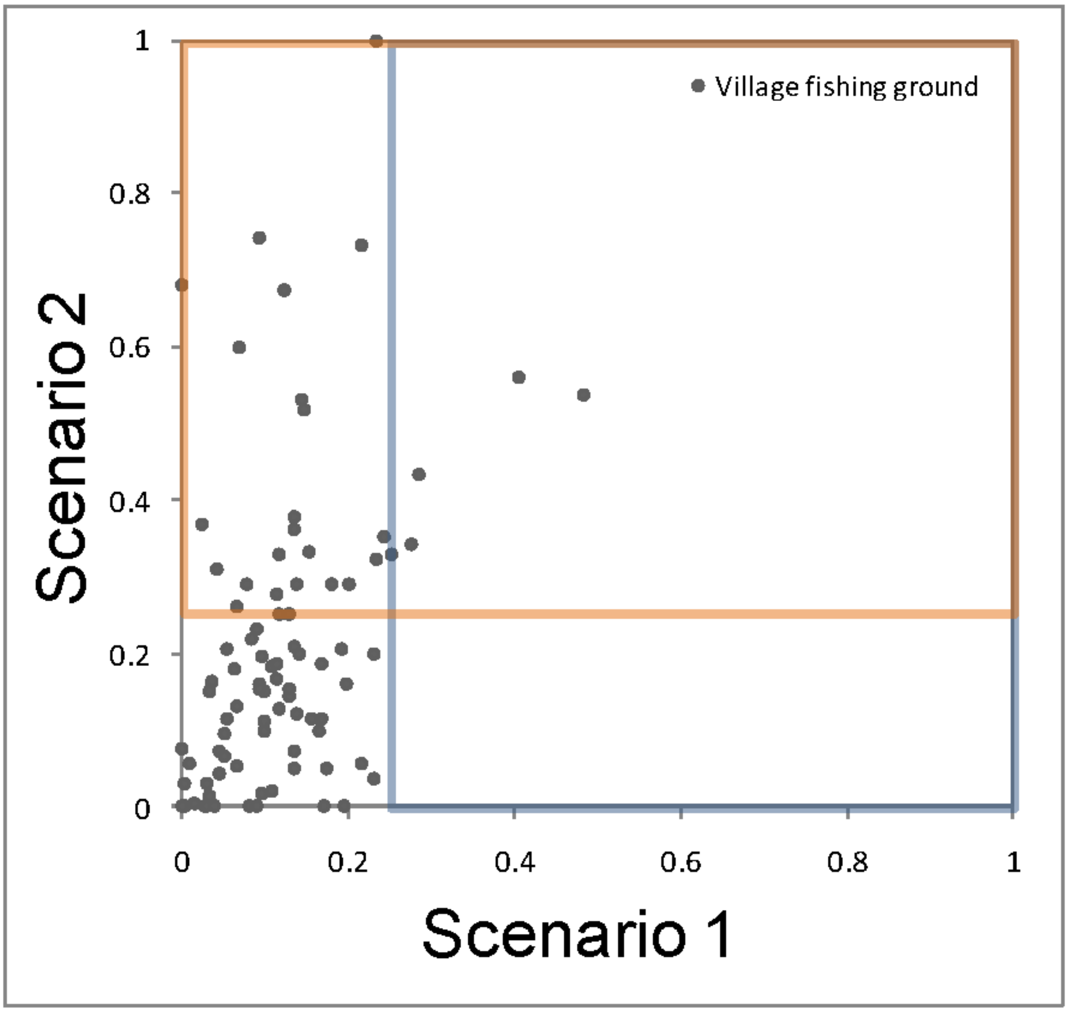


Figure 12. Comparison of the proportion of village fishing grounds in no take zones under scenario 1 – prioritizing for two zones and scenario 2 – prioritizing for one zone. The goal is to have less than 25% of the fishing ground in no take zones. If this is achieved in both scenarios the village fish ground will fall within the lower left hand box. In scenario 1, more than 25% of village fishing ground was allocated to a no take zones on two occassions– these are the two points that fall within the blue box. However in scenario 2, there are many fishing grounds with more than 25% of their area within no take zones – these are the points that fall within the orange box.

This scenario resulted in 33 out of 127 village fishing grounds having more than 25% of their area in the no-take zone. This included one village fishing ground in Southeast Misool MPA (Magey Village - Prawn) that had 100% of its grounds in the selected no-take zone. In contrast, Scenario 1 resulted in only four villages having over 25% of their fishing grounds selected for no-take zones.

3.5.2.3 Scenario 3 – incorporating proposals by communities and practitioners

During the second stakeholder workshop, practitioners who had been working with communities on the zoning plan for the Raja Ampat MPAs identified proposed areas for no-take zones (Figure 13i).

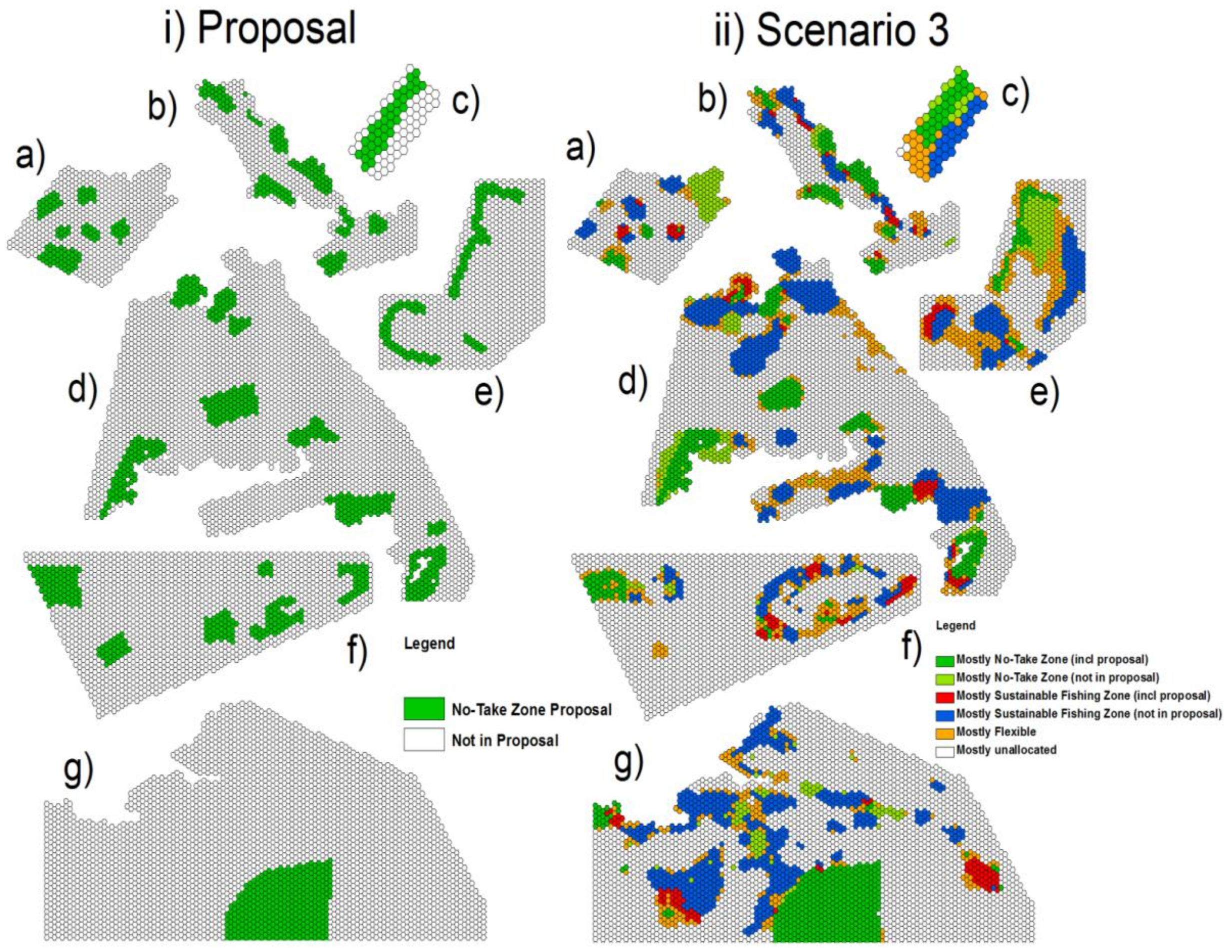


Figure 13i. Map of proposed no take areas by practitioners and communities provided at workshop 2.

Figure 13ii: candidate no-take and sustainable fishing areas for scenario 3 (classified solution maps) including differentiation between proposal and non proposal areas. Each planning unit is classified according to the proportion of times the planning unit was selected for a specific zone as follows: "mostly no-take" (selection frequency = 60-100% for no-take zone), "mostly sustainable fishing" (selection frequency = 60-100% for sustainable fishing zone), "mostly unallocated" (selection frequency = 60-100% for unallocated zone), and "flexible" (the rest of the planning units selected). a) Sayang-Wayang MPA, b) Ayau-Asia MPA northern section, c) Ayau-Asia MPA south section, d), West Waigeo MPA, e) Mayalibit Bay MPA, f) Dampier Strait MPA, g) Kofiau and Boo Islands MPA and h) Southeast Misool MPA.

Comparing the two side by side allows visual interpretation of overlap between location of proposed no-take areas and no-take areas identified in analysis; this indicates which parts of the proposal might be reconsidered due to their importance as a fishing zone, and which additional areas might be considered for inclusion in a no-take zone that were not included in the proposal.

The contribution of these proposed areas to goals for conservation targets as well as their impact on fishing grounds previously identified by communities is illustrated in Figures 14 and 15. The community-proposed no-take areas would achieve only 32% of conservation goals across the network. Also, protecting just community-proposed areas would result in several of the target being overrepresented and would also lead to underrepresentation in some cases, including ten targets which would not be represented at all (Figure 14).

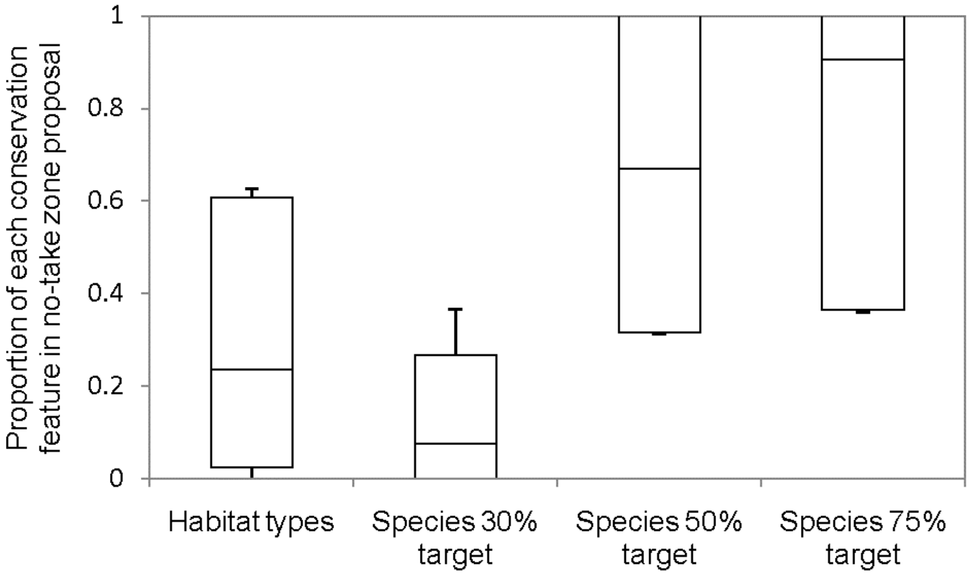


Figure 14. The proportion of no-take targets in proposed areas showing that in all categories there was both under and over representation of habitats and species in the areas selected by communities only. The proportion of each no-take zone target summed by species and habitats captured by the areas proposed by practitioners. For species, there were three different goals used. The boxplot shows the range, upper and lower quartiles and median values.

Community-proposed no-take areas would also impact goals for access to mapped fishing grounds. The analysis showed 52 out of 136 (38%) fishing grounds having over 25% of their distribution in the preferred no-take zones (Figure 15). Under this scenario, goals for sustainable fishing zones could not be achieved in any of the MPAs.

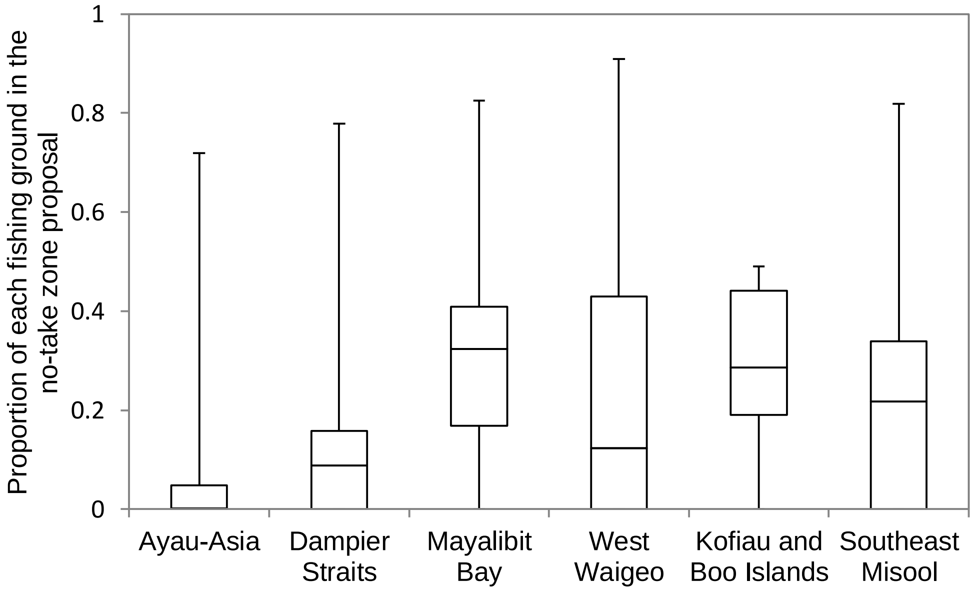


Figure 15. The proportion of fishing grounds at each Raja Ampat MPA in proposed no take areas. The boxplot shows the range, upper and lower quartiles and median values.

Since community-proposed areas did not meet conservation or fisheries objectives simultaneously, we ran a futher analysis to find solutions which met goals for conservation targets and fishing grounds and retained a proportion of the community-preferred areas. In this analysis we targeted 60% of the community-proposed no-take areas (Grantham et al. 2012). Figure 13ii illustrates the location of potential areas for fishing and no-take zones, differentiating between community-proposed areas and additional areas identified by the analysis to meet the conservation and sustainable fisheries goals. Figure13ii highlights the importance of a number of additional areas for conservation; some are located adjacent to proposed no-take areas and others are further away. Areas in light green are likely to be the most important to include as no-take zones in addition to the community-proposed areas.

3.5.3 How to use these tools?

This project provides the region with a strong foundation for a variety of marine spatial planning and management applications. The major Decision Support Tools from this project were:

a) Spatial information (i.e., spatial database and map viewer application);
b) Maps of coral reefs, sea grass and mangrove habitats;
c) Maps of resource use;
d) Maps of key species distribution;
e) Maps of key species habitats (e.g. feeding and reproductive grounds);
f) Maps showing arrangements of potential areas for sustainable fishing and conservation zones within the MPA network under different scenarios;
g) Plots illustrating the percentage of conservation targets and fishing grounds captured in potential areas for conservation and sustainable fishing zones, respectively; and
h) A Marxan with Zones analysis set up for Raja Ampat which can be updated and re-run under new scenarios.

Stakeholders can access a variety of spatial information to support decision-making for a range of management processes. For example, the information gathered on origin of fishers through the resource use monitoring program can be used to inform management of illegal and unreported fishing. Questions such as “what percentage of fishing activities is locally based?” “what are the areas targeted by fishers outside the area?” “what are the fishing gears mostly used by outside fishers?” can be answered.

The maps generated by the analysis outlined in Section 3.4.2 can help identify the location of important fishing and conservation areas to be included in future zoning plans. The classified solution and selection frequency maps (e.g. Figures 8 and 9) summarize the number of times specific areas were selected in our analysis for either conservation or fisheries, based on the objectives outlined above. The area's most frequently selected are likely to be important areas to be included in a future sustainable fishing zone; the areas least frequently selected are likely not to be critical to achieving either conservation or fisheries objectives. Information on specifically what percentage of features is captured (e.g. Figure 14) can be used to understand the total amount of targets captured given a specific zoning configuration. If, for example, decisions need to be made on whether to implement only conservation zones in specific locations, these maps can be used to understand the impact this decision will have on fishing grounds.

It is important to remember that the types of tools generated by this project provide decision support and should not be the only information considered by the decision-makers when developing MPA zoning plans. For example, the analysis output maps that we provided help identify areas that are important for conservation and fishing. It is also important to remember that these results are very dependent on the type and quality of information used, and the influence of specified goals in shaping analysis outputs (thus the maps generated). The potential areas highlighted as important are very much a function of these factors and should thus be considered along with other information such as additional stakeholder and community inputs, socioeconomic information and strategic plans for industry and infrastructure that could not be included in this analysis. These products should be considered as decision support – *not* decision-making.

Top to bottom, photos by: Salomina Tjoe/TNC, Dwi Aryo Handono/TNC, Andreas Muljadi/TNC

4. DISCUSSION

The need to address a number of management objectives in Raja Ampat under a common framework is apparent, and the zoning effort that the region is undertaking holds great promise to fill this need. This project was designed to support that process. We focused on two objectives: fishing and conservation. Our intent was to develop tools that would increase awareness of connections (ecological and sociocultural) across the network and help identify potential locations for future no-take and sustainable fishing zones. We wanted to enable stakeholders in Raja Ampat to visualize the consequences of specific decisions on the location of potential areas for zoning not for just their site, but for the network as a whole. We assembled a multi-objective database and built tools that can help decision-makers in the region consider conservation and fisheries objectives simultaneously. Our hope is that this will likely lead to increased compliance and reduced conflict and therefore more effectively managed MPAs. Stakeholder engagement was central to all project activities. To ensure participation, we conducted activities ranging from technical workshops to community meetings. These steps helped to engage key stakeholders, practitioners and government agencies, and to forge important partnerships. The resulting feedback was a key asset and greatly benefited the tools generated. Below is a discussion of lessons learned, challenges and recommendations for future work.

4.1 Zoning a network to address multiple objectives

As with all MPA networks, managing the Raja Ampat network requires tracking management activities and integrating information at multiple scales (site to regional); this can be challenging. When this project commenced, work was underway at each MPA site in Raja Ampat to identify zoning configurations that would help manage multiple uses within MPAs. However, there was limited ability early on in the planning process to include in individual zoning plans important information on ecosystem relationships and connectivity (ecological and social) between the MPAs. This project helped fill this gap by generating tools that could support zoning at individual sites while also considering network-wide information.

Given Raja Ampat's sociocultural context and the growing threats to marine resources in the region, there was a clear need to address a number of management objectives under a common framework. The establishment of a network of MPAs and their zoning that the region is undertaking holds great promise to fill this need. Zoning can serve as an integrative process in which "planners must recognize connections, including connections between different elements in an ecosystem, between land and sea, between humans and nature, and between uses of ocean resources or ocean space and the ability of ecosystems to deliver important goods and services" (Agardy 2010). This project has helped lay the groundwork for increased dialogue in Raja Ampat– an objective clearly crucial for ocean management (Barale et al. 2009) – by providing tools that will facilitate open debate between sectors and identify conflicts and means of coexistence.

We have mainly focused on two objectives: fishing and biodiversity conservation. However, we realize that the growing pressure on the Raja Ampat region is not simply a matter of allocating harvestable resources (such as fish) among competing users. As the demand for new uses of marine space in Raja Ampat increases, it will become a matter of resolving competing claims among users of marine resources (both within and outside MPAS) for different purposes. This will raise to a new level the challenge of avoiding or managing conflicts among alternative uses. This project helps meet this challenge by providing a solid base layer of information and examples of the type of tools and activities that are integral to any zoning initiative, regardless of the scale and number of objectives that are addressed.

4.2 Building spatial databases that can address multiple objectives

Building a spatial information base that effectively represents ocean uses and the habitats supporting them requires integrating a wide variety of ecological, sociocultural and economic information. As outlined above (Section 3.2), collating and integrating datasets was a central part of our work in Raja Ampat. This can take considerable time and resources depending on data availability and the need to generate new data when gaps are identified. The scales of this type of information are often very different, and integrating them to generate a balanced view of the system is complex. While considerable information has been collected in Raja Ampat, prioritizing its collection and combining information from different sources and at different scales to produce a network-wide view proved to be challenging. In any zoning effort, making balanced decisions on investments of data collection resources, acknowledging the mismatch in scale between types of data, and making transparent choices to overcome this challenge are essential.

This project filled important data gaps for Raja Ampat, prioritizing the collection of ecological, sociocultural and economic information and conducting rapid assessment surveys to build the information base for zoning. The following strategic investments would strengthen this integrated information base for future multi-objective marine planning efforts in Raja Ampat and the wider Bird's Head Seascape:

- Continue to collect data at individual MPA sites in a similar and consistent way, to enable data to be compiled, analyzed and integrated both at the individual MPA and network level;
- Invest in the collection of data and synthesis of information on resource use, to ensure a continued understanding of changes in existing uses and to plan for new users that may need

specific management in the future. For example, expand existing monitoring programs to include: productivity and socioeconomic value of specific fisheries, location of historical versus current fisheries grounds, and species-specific information such as biomass, effort etc. for both reef and non-reef fisheries. (Also see section below on including fisheries information);

- Invest resources in the maintenance and management (including adaptive management) of a Raja Ampat (and eventually Bird's Head Seascape scale) database;
- Ensure database resides and is maintained by local government agencies and universities – this will facilitate the use of this data in broader coastal and marine spatial planning processes in the region;
- Prioritize collection of information outside MPAs to document both ecological as well as sociocultural and economic characteristics of Bird's Head Seascape;
- Expand collection of coastal habitat data to include more types of habitat (e.g. mangrove and seagrass) and associated stressors (e.g. riverine inputs); and
- Collect data on critical offshore habitat, both benthic and pelagic, using fairly simple approaches (for examples see Kenny et al. 2003, Game et al. 2009, Agostini et al. 2010, Schill et al. 2011).

4.3 Including fisheries information

A major objective of the Raja Ampat MPA network is supporting sustainable fisheries. What makes a sustainable fishery is complex (Hilborn et al. 2004, Cinner et al. 2009), and representing this in a systematic spatial and adaptive planning framework or process such as this one is difficult. Targeting village fishing grounds as a whole was the main approach we used to document the nature of fishing in Raja Ampat. With this approach a number of important characteristics related to where communities fish and how grounds are valued were either partially or wholly undocumented; for example what part of the grounds was the most productive, what part of the grounds contributed to reef versus non reef fisheries (e.g. coastal pelagics). While we considered one important aspect for fisheries in Raja Ampat (ensuring community livelihood and food access needs), there are obviously a number of others that could have been represented. For example ensuring both reef and non-reef key trophic species (e.g. small pelagics and apex predators), important life history habitats for both of these, and the interactions between key species are documented and taken into account when designing a no take or a sustainable fishing zone. Representing these in our analysis would have required additional data collection and modeling efforts beyond the scope of this project. Developing approaches to effectively capture this kind of information will require further investments in monitoring and science efforts. A wider characterization of Raja Ampat fisheries and fishing grounds to include the aspect we mention above should be considered for future mapping efforts.

4.4 Getting stakeholder input

For any zoning plan to be achievable – that is, supported by user groups and feasible in the local context – activities supporting its design should be as participatory as possible. This project actively engaged local communities, practitioners and government agencies in Raja Ampat. To ensure participation, the project conducted activities ranging from technical workshops to formal and informal community meetings. These steps helped engage key stakeholders and forge important partnerships. The resulting feedback greatly benefited the Decision Support Tools generated. Information flowed in both directions, both to and from stakeholders and the project team, an essential ingredient of any marine zoning process (Agardy 2010). With the Decision Support Tools now available for Raja Ampat, the process of engaging the public and further developing an appreciation for the ecosystem services provided by the ocean is more feasible. It is our hope that some of the tools developed during this project can continue to be leveraged by practitioners and decision-makers in Raja Ampat and serve as a model for other MPA network zoning efforts in Indonesia and the broader Coral Triangle region. Many of the approaches and tools we have used can also be adapted by practitioners facing similar challenges in other parts of the world.

4.5 Using systematic planning tools

The systematic conservation planning tool we used (Marxan with Zones) helped organize a wide range of information and assign actions to specific locations across the MPA network. Like any modeling tool, Marxan with Zones presents a set of challenges and opportunities. There is a danger that these tools, as well as the choices and assumptions made to build them, are not understood by stakeholders; this will make them less inclined to use the suite of other decision support products generated along the way (Agostini et al. 2010). In order for these tools to be useful, it is important that they are applied in the most transparent manner, with stakeholder involvement in the definitions of zoning or management objectives, key assumptions and parameters. The participatory process that took place during this project facilitated stakeholder input at a number of key points in the analysis, producing zoning scenarios that reflected community and government input.

The Marxan with Zones software represents a new generation of systematic planning tools in which multiple objectives and needs of people are considered in one planning framework. While Marxan with Zones is an evolution of the widely used Marxan software and may seem similar in look and feel, the two have important differences in information requirements. In addition to ecological data, Marxan with Zones requires a considerable amount of data on ecosystem services and people's aspirations regarding marine and coastal uses. This difference needs to be considered carefully when evaluating data needs and the required resources for data collection and analysis. Model outputs are only as good as the data used to build them. Likewise, their impact is only as good as the ability of decision makers to understand their outputs. While the need to integrate ecological, sociocultural and economic information into conservation planning efforts is increasingly apparent, there are still few examples of projects that have done so with Marxan-based modeling for marine systems (Klein et al. 2009, Watts et al. 2009, Agostini et al. 2010). We should continue to prioritize activities that identify, distill, and communicate lessons learned from these projects and that strengthen this type of integration.

4.6 Moving from network to wider "seascape" zoning

MPA networks are an essential component of the marine management toolbox. They serve to connect physical sites both ecologically (linking ecologically critical sites) and socially (linking people and institutions) (Agardy and Wilkinson 2004). However, as is the case in Raja Ampat, MPAs as networks are usually separated by large distances, and uses in areas outside the MPAs should also be addressed. Failure to do so could lead to outside threats affecting the integrity of the MPAs and therefore result in ineffective protection (Agardy 2010). The importance of looking at areas beyond protected area boundaries has increasingly been acknowledged by planners and managers around the world, as their condition will have profound influence on these islands of protection (MEAM 2008). This raises the importance of considering management tools such as ocean zoning that will facilitate sustainable development in the wider Bird's Head Seascape. Ocean zoning will allow protection of special places and valuable ecosystem services through place-based conservation, while also addressing "the condition of the wider ecosystems in which these islands of protection sit" (Agardy 2010). The current MPA network in Raja Ampat and the related zoning activities are at the core of that important place-based conservation. Both the tools generated and the process outlined during this project can serve as a model for future zoning activities at the wider Bird's Head Seascape scale. Scaling up to the wider Bird's Head Seascape will provide a number of benefits, including a harmonization with terrestrial land-use planning and will yield tools to facilitate stronger fisheries management that can help secure local community access to food and livelihood in the years to come.

Photo by: Feri Latief

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Appendix 1a: Participants at the first Raja Ampat MPA zoning stakeholder workshop (16-17 February, 2009) in Sorong, West Papua

Name	Organization
Jo Wilson	The Nature Conservancy-Indonesia Marine Program
Chris Rotinsulu	Conservation International-Indonesia
Vera Agostini	The Nature Conservancy-Global Marine Initiative
Hedley Grantham	University of Queensland
Sangeeta Mangubhai	The Nature Conservancy-Indonesia Marine Program
Andreas H. Muljadi	The Nature Conservancy-Indonesia Marine Program
Muhajir	The Nature Conservancy-Indonesia Marine Program
Rein Paat	The Nature Conservancy-Indonesia Marine Program
Arief Darmawan	The Nature Conservancy-Indonesia Marine Program
Heintje Rotinsulu	Conservation International-Indonesia
Kris Thebu	Conservation International-Indonesia
N. Ismu H.	Conservation International-Indonesia
Bram Goram Gaman	Conservation International-Indonesia
Erdi Lazuardi	Conservation International-Indonesia
Meity Mongdong	Conservation International-Indonesia
Katherina	Conservation International-Indonesia
Charles Imbir	Conservation International-Indonesia
Charles Tawaru	Conservation International-Indonesia
Julianus Rahawarin	Department of Fisheries Raja Ampat
Ismail Tampi	COREMAP II Raja Ampat
Frans G.	Department of Environment Raja Ampat
Yulianus Thebu	Department of Environment Raja Ampat
Danny Pattipeilohy	Nature Conservation Agency of the Ministry of Forestry
Salmon Weyai	Nazaret Papua Foundation
Ferdiel Ballawu	Papua Turtle Foundation

Appendix 1b: Participants at the second Raja Ampat MPA zoning stakeholder workshop (9-10 February 2010) in Sorong, West Papua

Name	Organisation
Joanne Wilson	The Nature Conservancy-Indonesia Marine Program
Chris Rotinsulu	Conservation International-Indonesia
Hedley Grantham	University of Queensland
Mike Beck	The Nature Conservancy-Global Marine Team
Sangeeta Mangubhai	The Nature Conservancy-Indonesia Marine Program
Lukas Rumetna	The Nature Conservancy-Indonesia Marine Program
Reinhart Paat	The Nature Conservancy-Indonesia Marine Program
Mohammed Syakir	The Nature Conservancy-Indonesia Marine Program
Mad Korebima	The Nature Conservancy-Indonesia Marine Program
Andreas Muljadi	The Nature Conservancy-Indonesia Marine Program
Muhajir	The Nature Conservancy-Indonesia Marine Program
Rachmat Saleh	The Nature Conservancy-Indonesia Marine Program
Mark Erdmann	Conservation International-Indonesia
Crissy Huffard	Conservation International-Indonesia
Meity Mongdong	Conservation International-Indonesia
Alberth Negore	Conservation International-Indonesia
SofyanAlting	Conservation International-Indonesia
RonaldMambrasar	Conservation International-Indonesia
Kris Thebu	Conservation International-Indonesia
Rudy Dimara	Conservation International-Indonesia
Bram Goram	Conservation International-Indonesia
Erdi Lazuardi	Conservation International-Indonesia
Obeth Rayar	Conservation International-Indonesia
Anis Mambrisau	Conservation International-Indonesia
Adri Kaiba	Department of Fisheries Raja Ampat
Syafri Tuharea	Department of Fisheries Raja Ampat
Danny Pattypeilohy	Nature Conservation Agency of the Ministry of Forestry
Taufik Haryanto	Nature Conservation Agency of the Ministry of Forestry
Julianus Rahawarin	COREMAP II Raja Ampat
Ismail Tampi	COREMAP II Raja Ampat

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