PAPUA NEW GUINEA

Conservation and
Environment Protection
Authority

LAND-SEA CONSERVATION ASSESSMENT FOR PAPUA NEW GUINEA

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Cover Image: Aerial photo of the coast of New Guinea with jungles and deforestation, PNG © Byelikova Oksana/ Shutterstock

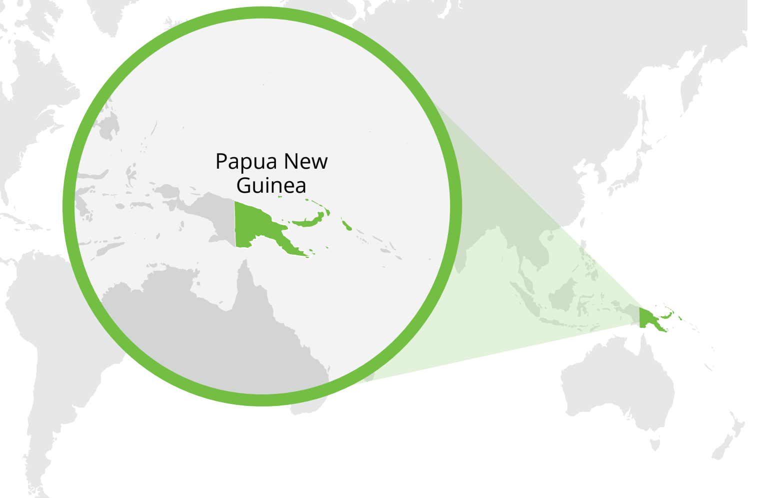
TABLE OF CONTENTS

East New Britain Province is one of many with ecotourism potential © Alice Plate/ UNDP

ACRONYMS

AOI	Areas of Interest
CA	Conservation Area
CBD	Convention on Biological Diversity
CEPA	Conservation Environment Protection Authority
CNA	Conservation Needs Assessment
GEF	Global Environment Facility
GIS	Geographic Information System
LMMA	Locally Managed Marine Area
MRA	Mineral Resources Authority
PA	Protected Area
PNG	Papua New Guinea
PNGFA	Papua New Guinea Forest Authority
PoWPA	Programme of Work for Protected Area
TNC	The Nature Conservancy
UQ	University of Queensland
WHS	World Heritage Site
WMA	Wildlife Management Area
WCS	Wildlife Conservation Society
WWF	World Wildlife Fund

1. EXECUTIVE SUMMARY



Papua New Guinea (PNG) is committed to the establishment of a network of protected areas to fulfil national and international commitments. The primary objective of this assessment was to provide an updated set of conservation priorities by integrating Terrestrial and Marine Programme of Works on Protected Areas (PoWPA) in PNG; this set of conservation priorities (see Figure 1) can be used as a roadmap for meeting conservation targets that fulfill PNG's global conservation commitments (e.g. under the CBD Aichi 11 targets) as well as national targets (such as the Protected Areas Policy). These areas were vetted by experts through a series of workshops and a subset of these priorities, 'Areas of Interest' (AOIs), were identified as areas critical for immediate conservation attention (Figure 2).

PNG contains a wealth of biodiversity. PNG has a land area of 461,690 km^2 with tropical forests, savannah grass plains, big rivers and deltas, swamps and lagoons, with numerous islands and atolls to the east and north east of the country. The main island of New Guinea supports an estimated 5–9% of the world's terrestrial biodiversity in less than 1% of the land area. Similarly, the marine environment of PNG is highly diverse and productive; PNG waters are considered part of the Coral Triangle, the area of the world's highest known marine biological diversity. Its coral reefs and associated marine habitat are home to about 2,800 species of fishes, about 10% of the world total. The relative importance of both the forests and inshore reef environments to PNG subsistence and commercial livelihoods emphasizes the importance of considering the connections between the land and sea. Land-sea planning aims to connect the protection of terrestrial, coastal and marine habitats in order to ensure that forests that are upstream of important coral reefs or coastal habitats are intact, and therefore support the flows between upstream and downstream conservation values.

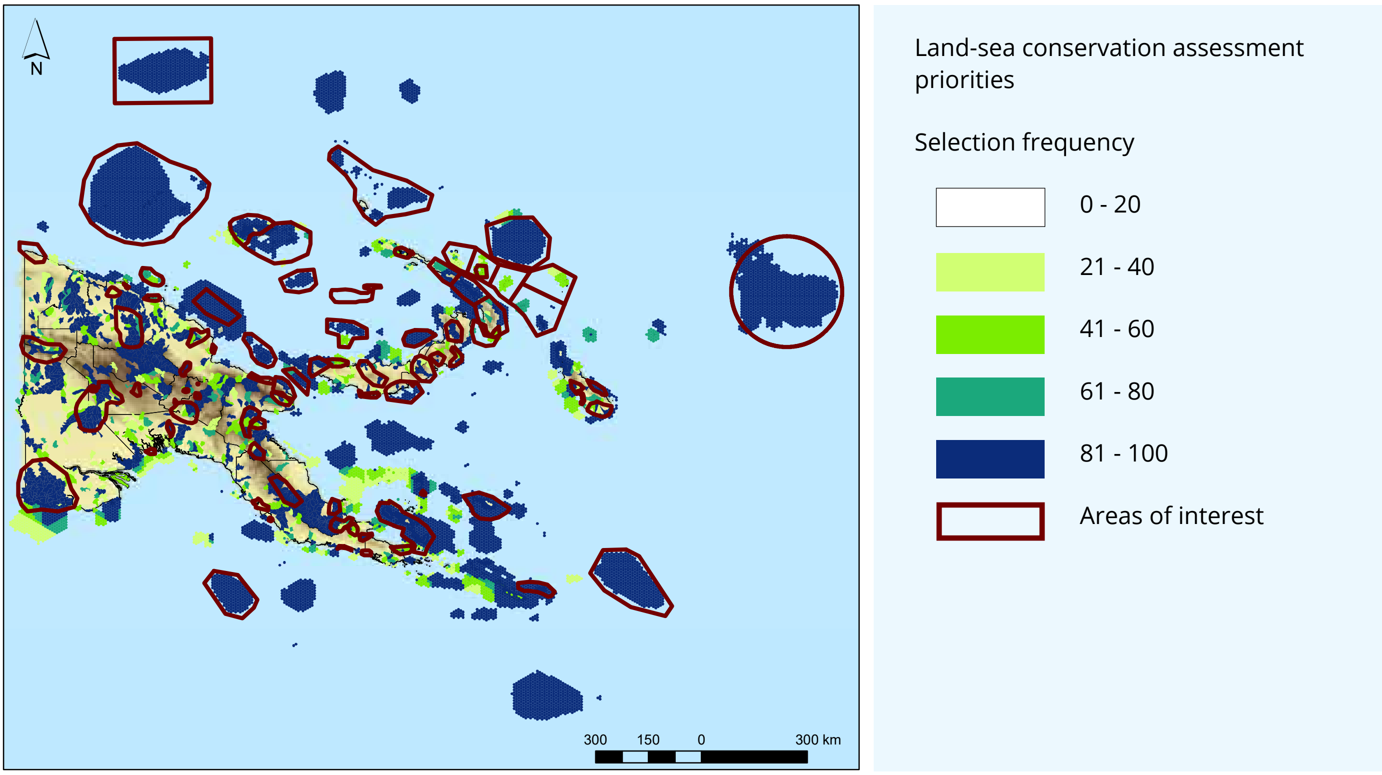
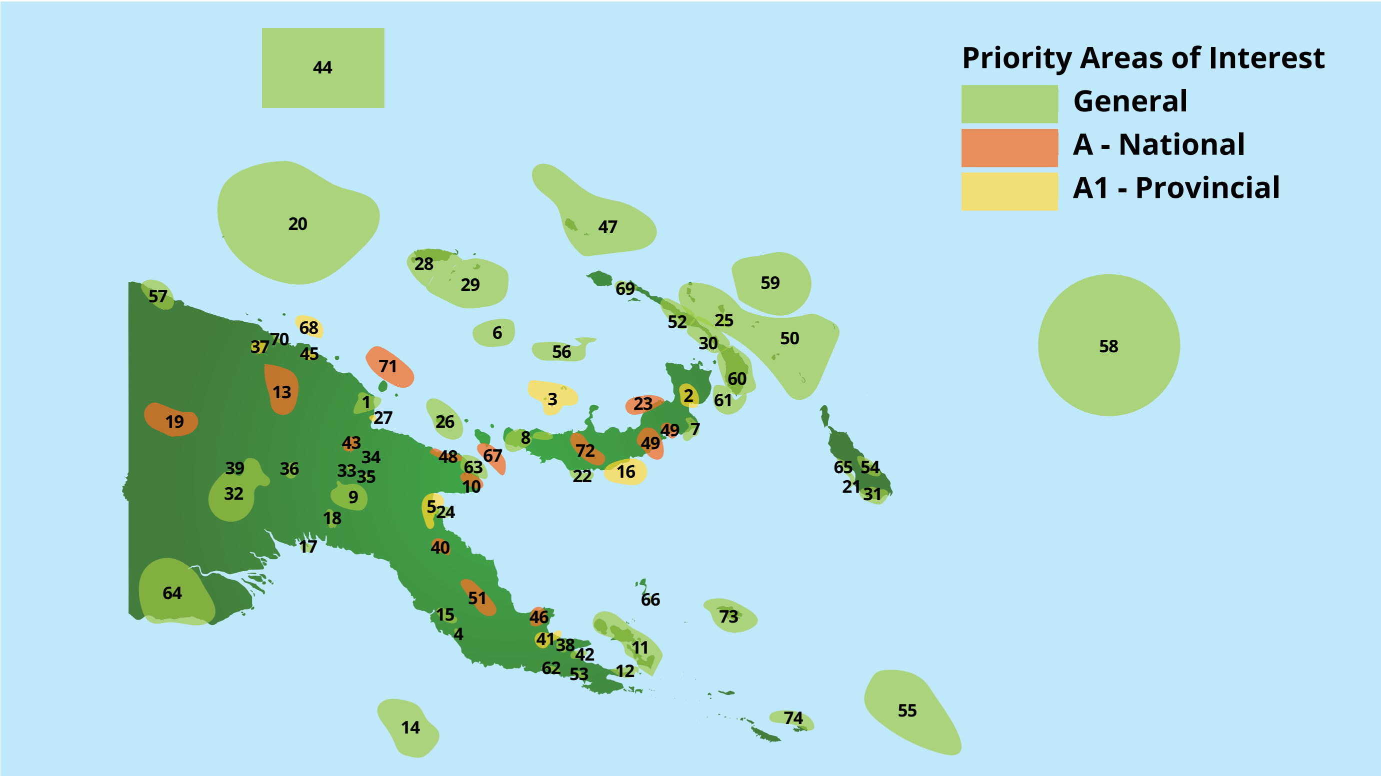


Figure 1: Final conservation priority areas (marxan selection frequency) identified in the conservation assessment.



1 Adelbert Range, RRE
2 Baining
3 Bali Witu Islands
4 Bootless Bay
5 Buang
6 Circular Reef
7 Coastal Pomio
8 Coastal West New Britain
9 Crater Mt
10 Cromwell Range
11 D'Entrescascau Islands
12 East Cape
13 East sepik WHA
14 Eastern Fields
15 Galley Reach
16 Gasmata
17 Goaribari Island
18 Gulf
19 Hindenberg Wall
20 Island chain northwest of Manus
21 Jaba River
22 Kandrian Coast
23 Kimbe Bay
24 Lake Trist
25 Lihir
26 Long Island
27 Madang Lagoon
28 Manus
29 Manus neighbouring islands
30 Mid New Ireland
31 Mt Balpi catchment area
32 Mt Bosavi
33 Mt Elimabari
34 Mt Gahavisuka
35 Mt Micheal
36 Mt Murray / Mt Giluwe
37 Mt Puru
38 Mt Simpson and Damen
39 Mt Sisa
40 Mt Strong
41 Mt Suckling
42 Mt Thompson
43 Mt Whilhelm
44 Murdogado Square
45 Murik Lakes
46 Musa Plains
47 Musau Group of Islands
48 N Huon Coast
49 Nakanai
50 NI east islands
51 North Owen Stanley
52 Northern New Ireland
53 Orangerie Bay
54 Pirung Eight Islands
55 Pocklington Reek
56 Proposed Whale Sanctuary
57 Scotchio
58 Sea Abyss (plains and hills)
59 Sea basin and plateau
60 Southern New Ireland
61 St Georges Channel
62 Table Bay
63 Tewae, RRE
64 Tonda
65 Torokina Caves
66 Vakuta Island
67 Vitiaz Strait
68 Vokeo Island group
69 Waters north of Kavieng
70 Wewak coast
71 North Coast Madang
72 Whiteman range
73 Woodlark Island
74 Yela Islandipsum

Figure 2: Areas of Interest (AOIs) are a subset of the conservation assessment priorities that have been identified as areas critical for immediate conservation attention. Areas of Interest (AOIs) were identified through expert workshops in November 2016 and further vetted in March 2017 to identify National priorities (A) that should receive immediate investment and Provincial priorities (A1).

This assessment uses a systematic conservation planning approach; while there are many different approaches to identifying conservation priorities, systematic conservation planning was selected as it was the basis of the previous PoWPAs and provides a transparent process for identifying sets of areas that meet explicit targets (e.g. 17% of all terrestrial ecosystems). Specifically, the assessment used the decision support tool Marxan to identify priorities, and advances previous individual terrestrial and marine assessments by considering land-sea connections. It is worth noting that the assessment is focused on biological diversity and representing habitat features to support biological diversity. While other features such as geological diversity and cultural diversity are aspects of diversity worth conserving, the assessment was constrained by available data. Geological and cultural diversity were captured, where possible, through the expert workshops. However, a more comprehensive assessment of these aspects of diversity would include mapped features across PNG.

This assessment identifies areas of conservation priority, however it does not dictate the types of activities within these sites. Translation of these mapped areas into conservation action will require the Conservation and Environment Protection Authority (CEPA) to engage with local communities and customary landowners to identify socially acceptable and locally relevant management arrangements. There are a range of conservation strategies that can be used to protect sites identified as conservation priorities within this assessment; these range from legal mechanisms to informal community based arrangements to management planning and activities.

Huli Wigmen from the Tari Valley, PNG © Alison Green/ The Nature Conservancy

For a particular site, strategies for implementation would reflect further consultation with local stakeholders such as provincial government and local landholders. Thus, this assessment should be considered a guide for conservation, but should not be applied in isolation. Successful implementation of the assessment will require dynamic translation of priority areas into on ground action and sequential update of priorities as further knowledge is acquired and on-ground circumstances change. Dynamic planning and implementation is a challenge; the Marxan analysis and associated data sets have been delivered to CEPA, along with technical training, to support adaptive planning. This staff capacity is a critical aspect of successful ongoing implementation of conservation priorities identified within this assessment. The assessment, in conjunction with planning products such as factsheets and data sets, and technical training provide CEPA with a road map to achieving biodiversity conservation across PNG.

Tari Valley, PNG © Alison Green/ The Nature Conservancy

2. PLANNING CONTEXT

PROJECT SCOPE AND OBJECTIVES

Papua New Guinea (PNG) is committed to the establishment of a network of marine protected areas to fulfil national and international commitments. The primary objective of this assessment is to complete an updated priority setting exercise for biodiversity conservation by integrating Terrestrial and Marine PoWPAs in PNG.

Specifically, this assessment identifies a set of conservation priorities that meet conservation targets which fulfill international and national conservation obligations. Furthermore, it integrates land and sea priorities by considering ridge to reef processes that connect these systems. By taking a holistic ridge to reef approach this assessment ensures that the priorities leverage connections between these systems to deliver the best conservation results for connected ecosystems.

The priorities presented in this assessment are appropriate for a variety of conservation mechanisms, such as World Heritage Areas (WHA), national protected areas and community based management. The alignment of individual priority areas with appropriate conservation strategies and policy mechanisms will be a necessary aspect of implementing this assessment.

POLICY CONTEXT

The Papua New Guinea Policy on Protected Areas (2014, hereafter the Policy) was developed to provide the framework for the implementation of actions to achieve Goal Four of the National Constitution, as well as fulfil PNG's obligations under a number of international agreements. As a signatory to the United Nations Convention on Biological Diversity (CBD), PNG has committed by 2020 to establish a "comprehensive, effectively managed and ecologically-representative national system of protected areas"; this includes specific targets of at least 10% of coastal and marine areas and 17% of terrestrial areas in protected areas to slow the global loss of biodiversity (CBD 2010).

Under the Policy, the Conservation and Environment Protection Authority (CEPA) commits to the establishment of the PNG Protected Area Network. The policy provides guidelines for the selection, design and management of protected areas in PNG.

Inland Madang, PNG © Nate Peterson/ The Nature Conservancy

PNG has identified nine terrestrial and five marine ecoregions for the purpose of reporting units for assessing the status of species and ecosystems and their protection in PNG's Protected Area Network, and these eco-regions are to be used in the monitoring and evaluation framework for the PNG Government's current natural resource management initiatives.

The PNG Protected Area Network will be comprised of two groups of Protected Areas: National protected areas — gazetted and managed under national legislation. Includes national marine sanctuaries. Regional protected areas — gazetted through provincial government legislation. Includes Locally Managed Marine Areas.

The Policy articulates the following targets for terrestrial protected areas:

- 17% of land systems
- All remaining occurrences of rare and endangered ecosystems should be reserved or protected by other means as far as is practicable.

The Policy articulates the following targets for marine protected areas:

- 10% of territorial waters and the coastline within a variety of marine protected areas by 2025 (CBD targets). Minimum of one million hectares (PNG 2050 Vision).
- 25% of the above target (i.e. 2.5% of territorial waters) under a combination of no-take zones and zones which allow fishing only by customary landowners for subsistence use by 2025.
- 10% of offshore areas outside territorial waters but within the Exclusive Economic Zone (EEZ) will be included in national marine sanctuaries by 2025.

3. SITUATION ANALYSIS

CURRENT STATUS AND TRENDS IN PAPUA NEW GUINEA

Existing protected areas

Approximately 4% of PNG's terrestrial area is protected in 53 protected areas. There are currently 2 Ramsar sites protecting freshwater values as well as 12 locally managed marine areas and 3 protected seascapes protecting marine values. Of the 53 terrestrial protected areas, 32 terrestrial wildlife management areas (WMAs) and 8 national parks have been formally gazetted, covering just 1.29 million hectares or 2.8% of PNG's total land area. In a recent assessment by Shearman and Bryan (2011), these protected areas included a total of 542,166 ha of rainforest, 54,332 ha of swamp forest and 8,892 ha of mangroves in 2002. This area of forest represents 1.9% of the total rainforest estate as well as 1.6% of the swamp forest and 1.5% of the mangroves. Similarly, only 37 of PNG's 73 forested biomes were represented in protected areas in 2002, and only 6 of these had 10% or more of their area contained in a protected area.

The recent gap analysis for terrestrial biodiversity in protected areas found only 14% of the fauna evaluated are represented within the existing protected area system at greater than 10% (Lipsett-Moore et al. 2010). Similarly, the current marine protected area system protects only 2.2% of the total reef habitat of PNG. Critical habitats for marine turtles are currently significantly under-represented (<2% of total area in reserves), less than 1% of important bird areas are protected, and there are no reserves currently protecting critical whale habitat. Only 12% of marine ecosystems meet or exceed a10% representation target.

Since Independence in 1975 there has been a significant shift in protected areas from those that exclude people (e.g. national parks) to those where people are a part of the protected area system (wildlife management areas and more recently a conservation area (YUS)). Given that 97% of the land in PNG is under customary ownership, it is appropriate that protected areas are inclusive rather than exclusive of people.

> ***"73% of PNG's protected areas have minimal or no management structure."***

A review for the World Bank/WWF Alliance for Forest Conservation and Sustainable Use showed that 73% of PNG's protected areas have minimal or no management structure, 16% had no management at all, 8% had a management structure but there were serious gaps, and only 3% were well managed with a good infrastructure (IUCN, 1999:26). The lack of effective management of existing protected areas was reiterated in the more recent PNG Rapid Assessment and Prioritisation of Protected Areas Management (RAPPAM) Report (Chatterton et al. 2009). Shearman et al. (Shearman et al. 2009), found that 24% of PNG's forest has been cleared or degraded during the period from 1972–2002. Over this period, forests within protected areas have experienced an overall decline of 8.9% (6.7% cleared, 2.2% degraded) (Shearman & Bryan 2011). While this suggests that forests within protected areas are better protected than forests overall, which had a country average of 24% change (Shearman et al. 2009), the wide variation in the change indicates protected area effects are heterogenous: six protected areas had no forest change but another six had more than 50% of their 1972 forest area cleared or degraded, and four had 99% of their extent deforested or degraded by 2002. A further 16% of rainforest within protected areas has been allocated for logging. This again demonstrates the lack of effective management, protection and/or conservation within existing protected areas.

Ambua Lodge, PNG © Alison Green/ The Nature Conservancy

Kerosene River, West New Britain © Nate Peterson/ The Nature Conservancy

Biodiversity

Terrestrial

PNG has a land area of 461,690 km^2 with tropical forests, savannah grass plains, big rivers and deltas, swamps and lagoons, with numerous islands and atolls to the east and north east of the country. The main island of New Guinea supports an estimated 5–9% of the world's terrestrial biodiversity in less than 1% of the land area (Mittermeier et al. 1998). It contains the world's third largest contiguous area of tropical rainforest and habitats ranging from alpine grasslands to cloud forests to lowland wet tropical forests, swamps and dry sclerophyll woodlands. The larger islands of PNG include Manus, New Ireland, New Britain and Bougainville, while the Milne Bay Province is comprised with a diversity of island chains.

PNG has more than 18,894 described plant species, 719 birds, 271 mammals, 227 reptiles, 266 amphibians, 341 freshwater fish and an unknown number of invertebrate species (Vié et al. 2009). Overall approximately a third of the species are endemic to PNG and more than 70% are endemic to Papuasia.

Knowledge of the threat status of biodiversity in PNG is poor. Available data from the IUCN Red List suggest the current status of species in PNG is as follows: 1 extinct, 36 critically endangered, 49 endangered, 365 vulnerable, 288 near threatened and 1,289 Least Concern (Vié et al. 2009). Moreover, because one in five assessed species in PNG is endemic, with the highest number of endemic mammals globally, loss of species in PNG generally means a higher likelihood of extinction. Given the rapid rates of forest conversion and degradation and increasing hunting pressure, it is highly likely that many more species will be added to the list and that existing listed species will move to an elevated threat status.

> ***"PNG has some of the largest unpolluted tropical freshwater systems in the Asia Pacific region."***

Marine

The marine environment of PNG is large, complex and highly biodiverse — it includes inshore lagoons, fringing and barrier reef systems, shallow banks and extends into very deep offshore areas encompassing slope, abyssal plain, trenches and ridges, seamounts and deep ocean vents. PNG waters are considered part of the Coral Triangle, the area of the world's highest known marine biological diversity. Its coral reefs and associated marine habitat are home to about 2,800 species of fishes, about 10% of the world total. Almost all reef types found in PNG waters are within fringing and/or barrier reefs, with an estimated area of 40,000 km^2. In addition, PNG has some of the largest unpolluted tropical freshwater systems in the Asia Pacific region. Coastal habitats encompass 46,000 km^2 of estuaries, bays, lagoons and coral reefs with the estuaries accounting for 6,000 km^2 (Manoka & Kolkolo 2001).

Aerial view of roads cutting through forests in Highlands Region, PNG © Alison Green/ The Nature Conservancy

Threats

The rich resources and vast size of the PNG marine environment offer huge opportunities for the PNG people, but also create significant challenges for effective and sustainable management, especially in the face of increasing pressure from a growing population and effects of climate change. Threats to terrestrial and marine biodiversity and resources in PNG are varied and interlinked. Key threats have been identified as priorities in the PNG Marine Program (DEC NFA and the NCC 2013) and the recent terrestrial PoWPA (Lipsett-Moore et al. 2010), and are outlined below.

Rapidly expanding human population

PNG's human population was estimated at 7,275,324 in 2011 (NSO 2011). The population growth rate has increased steadily from 2.2% in 1980 to 3.1% today (NSO 2011). Eighty percent of PNG's population is dependent on subsistence agriculture for food, and increasingly, small scale cash crops which results in increased rates of forest conversion and degradation. In addition, it is also likely that traditional hunting pressure has increased, although there is no available data. Population growth in coastal areas has been identified as a major threat to marine biodiversity in PNG (DEC NFA and the NCC 2013).

Industry

PNG has a nominal GDP of $6.0 billion USD with a growth rate of 6.2%. Major industries include mining, oil and natural gas, forestry, palm oil, coffee, cocoa, coconuts, palm oil, timber, tea, and vanilla. Almost all of these industries are expanding and all have impacts in terms of forest conversion and increased pollutants in water ways. There is significant interest in potential seabed mining activities in parts of the PNG marine environment (DEC and NFA 2009); due to the steep drop-offs associated with the bathymetric profile of PNG's marine area, areas of potential high prospectivity

can be located close to shore in populated areas. Pollution, especially related to runoff from inland mining activities and poor land management practices, and debris and sewage, have been identified as a key threatening process to coastal marine biodiversity (Shearman et al. 2009).

Forest conversion and degradation

PNG forests are being degraded at an annual rate of 1.41% (Shearman et al. 2008). For the period from 1972 to 2002, 48.2% of forest change was due to logging (0.9 million ha deforested; 2.9 million ha degraded), 45.6% (3.6 million ha) was cleared for subsistence agriculture, 4.4% due to forest fires, 1% due to plantations, and 0.6% due to mining (Shearman et al. 2008). It is estimated that by 2021 most commercially accessible forests will be degraded (Shearman et al. 2009). Most accessible forests are under logging concessions and the remaining accessible areas are subject to industrial agriculture or the impacts of a rapidly expanding human population.

Marine resource exploitation

Marine and coastal ecosystems are a vital part of the livelihood of the PNG people at all scales, from subsistence activities at a community scale to large scale economic development at a national scale. Fishing resources are vital both in coastal waters and extending into the open ocean. Fisheries resources provide subsistence for local communities, support rural livelihoods and provide significant revenue for the government. The total market value for PNG's fisheries catch is estimated at PGK 350–400 million annually on average, with tuna fisheries bringing in approximately half this value annually. Despite the richness of PNG fisheries resources and the substantial value of fisheries production in absolute terms the contribution to national GDP is small compared to other Pacific Island countries. There is a significant potential to increase the economic value and returns to PNG in this sector through better management and development programs (DEC and NFA 2009, DNPM 2010). PNG's tuna fisheries are set to expand in the near future, which will require regional and national negotiations around managing the fishery

Kavieng local fishers, PNG © Vanessa Adams/ University of Queensland across nations, given the crossboundary distribution of this resource. Unregulated fisheries also pose a major threat to marine resource sustainability. The PNG National Fisheries Authority (PNG NFA) plays a key role in protecting PNG's vast fishing zone from illegal, unreported and unregulated foreign fishing.

Land-use impacts on the coastal and marine environment

Land conversion for industry has impacts in terms of forest conversion and pollutants into water ways. Run-off from increased deforestation and agriculture in PNG has the potential to cause widespread degradation of coral reef habitats, reducing species richness and the complexity of coral reef habitat (Fabricius 2005; De'ath et al. 2012). Coastal habitats such as mangroves and seagrass are tightly connected to coral reefs through the provision of critical spawning and/or nursery grounds for many fish and invertebrate species (Beck et al. 2001; Mumby 2006), as well as providing feeding grounds for threatened dugong and turtle populations. These habitats are often directly affected by changes in land-use (Orth et al. 2006) (see Figure 2). Excess nutrients in run-off from fertilisers can increase algal cover in coastal habitats and reefs, whilst turbidity from sediments can hinder growth of corals and seagrass, with potential negative feedback effects for associated marine species. Studies suggest loss or degradation of coral reef habitats from eutrophication or edimentation due to terrestrial run-off may contribute to declines in fish biodiversity and abundance (Jones et al. 2004), compromising the sustainability of fisheries that rely on functioning and healthy ecosystems (Wilson et al. 2008) (see Figure 2).

Climate Change

The predicted impacts of climate change on biodiversity and people are many. The vulnerability of an ecosystem to climate change depends on its species' tolerance of change, the degree of change, and the other stresses that are already affecting it (Lawler 2009). Climate change is a key pressure on marine (Walther et al. 2002) and terrestrial ecosystems.

Impacts of climate change on protected areas include loss of habitat e.g. coastal areas to sea level rise, whilst in the marine environment, changes in sea surface temperature, and acidification can significantly reduce hard coral cover. An increase in extreme events (such as drought, storm surge, increased fire and flood risk, cyclones, and extreme temperatures) is likely, which can have significant flow-on effects for habitats and species.

Species may respond to a loss of climatic conditions in different ways, by:

1. Moving (migrating upward or poleward increase) because of more favourable climate
2. Population declines (due to limited migration potential, dispersal or shrinking suitable areas)
3. New pressures - disease and invasive plants and animals
4. Loss of key species - migratory, keystone, pollinators, predators, etc

Finally, expanding human pressures such as pollutants and resource over-exploitation may compound the negative effects of climate change on species and systems.

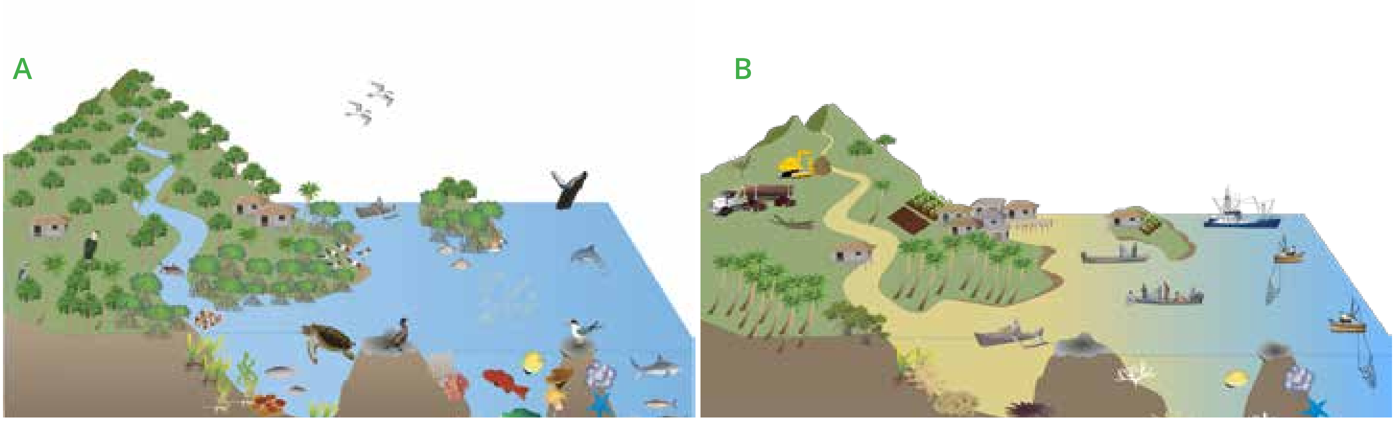


Figure 2: Schematic of land-sea ecosystem services, with A) showing healthy connectivity between coastal ecosystems with high productivity, and B) showing reduced marine productivity due to human activity.

4. PLANNING APPROACH

PROJECT SCOPE AND OBJECTIVES

The primary objective of this assessment is to complete an updated priority setting exercise for biodiversity conservation by integrating Terrestrial and Marine PoWPAs in Papua New Guinea (PNG). It therefore uses a systematic conservation planning approach as utilized by the previous assessments (Lipsett-Moore et al. 2010; Government of Papua New Guinea 2015). Specifically it uses the decision support tool Marxan (Ball et al. 2009) to identify priorities, and advances individual terrestrial and marine assessments by considering land-sea connections. It is worth noting that the assessment is focused on biological diversity and representing habitat features to support biological diversity. While other features such as geological diversity and cultural diversity are aspects of diversity worth conserving, we were constrained in our analysis by available data. Geological and cultural diversity were captured, where possible, through the expert workshops. However, a more comprehensive assessment would include mapped features across PNG. If data becomes available, these features could be included in future assessments as features with explicit conservation targets. Details of our approach and process are provided below.

SYSTEMATIC CONSERVATION PLANNING

In 2016, systematic conservation planning turned 33 years of age. Its inception is dated at 1983 (Pressey 2002), the year that Jamie Kirkpatrick published two papers that first used the principle of complementarity (a term coined later by Vane-Wright et al. 1991) to identify priority conservation areas. During the last three decades systematic conservation planning has become productive and influential, with numerous applications to regional conservation planning by government and non-government organisations (Groves 2008; Kareiva et al. 2014; Groves & Game 2016).

We follow the 11 stages of systematic conservation planning broadly defined to include the entire process of conservation decision-making from scoping and inception to decisions about priority areas, application, management, and monitoring (all 11 stages of Pressey & Bottrill 2009, Figure 3). As a basis for discussing the relationship between 'assessment' and 'implementation', we define assessment as stages 1–9 of the framework (see Figure 3) and implementation as stage 10. Stage 11 refers to post-implementation management and monitoring of conservation actions.

Systematic conservation planning stages

A

1. Scoping and costing the planning process
2. Indetifying and involving stakeholders
3. Describing the context for conservation areas
4. Identifying conservation goals
5. Collecting data on socio-economic variables and threats
6. Collecting data on biodiversity and other natural features
7. Setting conservation objectives
8. Reviewing current achievement of objectives
9. Selecting additional conservation areas
10. Applying conservation actions to selected areas
11. Maintaining and monitoring conservation areas

Figure 3: Systematic conservation planning stages. Stages 1–9 form the assessment phase of planning (Stages indicated by A in figure) while 10 and 11 are the implementation phase. We report here on the assessment phase of the land-sea conservation priority planning for PNG Source: (Pressey & Bottrill 2009)

LAND-SEA PLANNING

Land use, particularly large-scale agriculture and forestry, are major industries in PNG (Figure 2). Runoff from these activities and others (community gardens and urban areas) appears to be causing significant impacts on nearshore ecosystems in many regions of PNG (Green et al. 2007).

A report of land-use practices in New Britain concluded that there is damage to coral reefs in areas of New Britain from sedimentation due to logging and oil palm plantation development (Brodie and Turak 2004). In addition to empirical studies such as these, recent studies modeling the response of coastal habitats to oil palm impacts suggest coastal and near shore reefs are likely to experience a high amount of degradation from threats such as oil palm expansion.

We developed a linked land-sea model based on previous work by Tulloch et al. (2016) to create a run-off risk map for oil palm and land-use change, and identify the best-off and worst-off coastal regions given current conditions, and future land development (Appendix 2).

We link priorities from the previous marine conservation priorities to those from the initial terrestrial priorities, to identify areas of concern given existing conditions and current threats (runoff regimes, mining), and then ran a new prioritisation to avoid sites that are predicted to be heavily degraded or at risk.

This conservation assessment advances previous assessments by integrating land-uses and their impacts on connected marine ecosystems, and by linking terrestrial priorities to marine priorities. In doing so, we deliver a set of integrated spatial conservation priorities across terrestrial and marine environments in PNG to help guide on ground conservation action. This is aligned with PNG's Policy on Protected Areas of which a central pillar is the establishment and management of protected areas. The priorities identified in this assessment can be used in implementing the Policy by identifying areas of highest priority for potential protection and other conservation actions.

PLANNING UNITS

For terrestrial planning units, we used the HydroBASINS watershed boundaries for PNG created by HydroSHEDS (www.hydrosheds.org/page/hydrobasins). HydroSheds provides open-source readily available data on catchments, river flow, and other processes necessary as data inputs for the land-sea model (Lehner et al. 2008). Using the HydroSHEDS database at 15 arc-second resolution, watersheds were delineated in a consistent manner at different scales, and a hierarchical sub-basin breakdown was created following the topological concept of the Pfafstetter coding system. The resulting polygon layers are termed HydroBASINS and represent a subset of the HydroSHEDS database. There were a total of 3,301subcatchments in our terrestrial planning unit layer with an average area of 14,400 ha.

For the marine region, we used the same hexagonal planning units employed in the Marine Gap Analysis (Government of Papua New Guinea 2015). The EEZ of PNG was divided into 50,215 hexagonal planning units encompassing both deep and shallow water habitats and adjacent coastal areas where mangroves were present. Hexagonal planning units share an equal boundary with all neighbouring planning units, which helps maximize the efficiency of reserve selection when using the boundary length modifier in (BLM) Marxan. Each hexagon had an area of 5,000 hectares; a size deemed appropriate for both the scale of the analysis and the computing and processing time required by Marxan.

Given the marine PoWPA was completed 2 years ago (2014), and no new data was identified relating to offshore priorities, we locked in all priority areas identified in that exercise that were offshore and constrained our analysis to those marine planning units in the coastal shelf.

DATA COLLATION AND ANALYSIS FOR THE ASSESSMENT

There is a shortfall in the spatial knowledge of much of the fine-scale biodiversity in PNG. It is impossible to sample the full range of biodiversity across marine and terrestrial realms. In order to represent biodiversity effectively for conservation planning we need meaningful groupings or classifications that reflect the full range of species and systems - that is surrogates or substitutes for biodiversity. Previous conservation plans have used habitats and ecosystems as proxies for biodiversity when detailed information is lacking.

For the development of conservation target features for the conservation priority analyses, 3 types of features are being considered:

1. Broad surrogates 'coarse filter', e.g. land and vegetation systems, marine habitats
2. Special features 'fine filter', e.g. threatened species
3. Ecological and evolutionary processes, e.g. migration corridors, breeding sites

To enable the consideration of land-sea linkages in our updated prioritisations, we are also collating the following forms of data:

1. Geophysical processes, e.g. rainfall, rivers, catchments
2. Land and sea uses, e.g. fishing, forestry concessions, mining

We have collated all available and relevant data for PNG, which are described in more detail in Appendix 1. Only data that cover the extent of PNG land area and marine EEZ were considered for use in the analysis, due to spatial biases that might occur if patchy regional data was used. There are numbers of global datasets that provide information on landcover, climate, and geophysical properties, that meet the extent requirements (cover whole of PNG), many of these are at a scale too coarse to be used in a national or regional analysis, or are out-dated. We therefore endeavoured to obtain the most up-to-date biodiversity, geophysical, climate and social data

Table 1: Description of conservation features, associated data set, and targets for terrestrial and marine ecosystems

Type	Description	Number features	Target
Terrestrial			
Land systems	Abiotic land systems (81) stratified by ecoregions.	359	A 10% target was set for each abiotic land system class across Papua New Guinea.
Vegetation	Natural vegetation types (61 total: 36 Forests, 6 Woodland, 3 Savanna, 3 Scrub, 11 Grasslands, 1 Mangrove and 6 Non Vegetation Types) stratified by percentage disturbed and by ecoregion.	954	A 10% target was set for any natural vegetation type (e.g., forested, grassland, etc) in keeping with the previous PoWPA, stratified by each ecoregion. No targets were set for developed classes (e.g., bare, oil palm, timber plantation).
Fauna - Restricted Range Endemic Species	Restricted Range Endemic Species including Bird of Paradise (10), Tree Kangaroos (12), Reptiles and Amphibians (123), and Mammals (25).	170	Recognizing that restricted range endemic species are only found at a single site, these species were given 50% targets.
Fauna - Critically Endangered and Endangered terrestrial species	IUCN RedList Critically Endangered and Endangered terrestrial species ranges including mammals (27) and amphibians (1).	28	Given the coarse resolution of this data and large spatial extent for most of these features we applied a 5% target. Given the large ranges, sensitivity tests for these features revealed most met their representation targets in the prioritisations without requiring actual targets to be set.
Climate refugia	Climate refugia.	1	We used a threshold approach, where planning units with a probability of less than 0.25 (>25% chance of acting as a climate refugia) were targeted 5%.
Marine			
Biophysical habitat data	Habitat conservation features (oceanic geomorphological features (19), depth class (7), coastal mangroves (1), non-reef shallow shelf (1), coral reefs (169)) stratified by marine bioregion and ecoregion.	1575	We set a goal of 10% for all habitat conservation features stratified by marine bioregion and ecoregion. This reflects the CBD target of 10% protection for marine habitats.
Fauna	Areas important for shorebirds and seabirds (Beck's Petrel, Streaked Shearwater, Heinroth's Shearwater, Red-necked Phalarope, Brown and Black Noddy, Greater Sand Plover), Blue whale critical breeding sites, Sperm whale historical catches, Green turtle nesting sites, Leatherback turtle nesting sites.	10	A 20% target was set for each of these special features.
Reef fish spawning aggregation sites	Reef fish spawning aggregation sites.	34	A 50% target was set for all reef fish spawning aggregations.

Note: See Appendix 1 for details of datasets used at the finest scale possible. We chose as much open-source versions of the data as possible, to ensure that future plans or modifications would not be restricted by data accessibility or availability.

TARGETS

The full list of data sets and targets used is presented in Table 1 (see Appendix 1 for descriptions of datasets). Targets were set in collaboration with CEPA over the course of 2 workshops (Workshop 1 held March 2016 in Port Moresby, Workshop 2 held August 2016 in Brisbane, see Appendix 3 for workshop details).

COSTS AND CONSTRAINTS

Costs and constraints were set in collaboration with CEPA over the course of 2 workshops (Workshop 1 held March 2016 in Port Moresby, Workshop 2 held August 2016 in Brisbane, see Appendix 3 for workshop details). In order to avoid areas of high conflict we locked out areas identified as having existing or proposed mines, oil and gas. These were identified by buffering point data for these sites with a 5km buffer and locking out any catchments containing more than 25% mining oil or gas sites. We also avoided major towns and villages; note this pertains to only the largest towns and villages mapped, e.g. Port Moresby and Kavieng. The decision to avoid subcatchments with large human populations was agreed upon with CEPA in response to criticisms of the previous PoWPAs which selected areas such as Port Moresby and Kavieng. We used the census data to create buffers around all towns in PNG proportional to the population, with a maximum buffer of 10km around the biggest villages. We assigned any catchments with >25% of their area containing village buffer as unable to be selected for conservation priority (locked-out).

The land cost surface layer was initially derived from the previous PoWPA, which used socio-economic information as a proxy for cost of protection based on the 2000 population census data for PNG (NSO 2011). Each population census point was summed to provide a total population value for each hexagon. This provides the appropriate gradient for Marxan to work with, from populous areas where it is expensive to create and manage protected areas, to less populous areas where it is less expensive to create and manage protected areas and where human threats tend to be lower.

For the marine cost surface, we used a surrogate for fishing pressure to represent the lost opportunity costs of conservation, based on the same distance landingsweighted cost model used previously in the Marine Gap Analysis (2014). The relative cost of conservation was determined in terms of the opportunity cost to fisheries, calculated by determining the distance of each planning unit from ports, weighted by fisheries landings at those ports. Once combined, we standardized the marine and land cost values so that bounds were comparable.

CONNECTIVITY

We considered three types of connectivity within our planning: freshwater connectivity of our terrestrial planning units, marine connectivity of our marine planning units, and land-sea connections between our terrestrial and marine planning units taking into account freshwater runoff and plume modelling. We selected a BLM that balanced benefits and costs of increased connectivity.

Freshwater connectivity for land

We used asymmetric direction connectivity based on freshwater connections.

Shared boundaries for sea

We integrated connectivity within sea planning units by including shared boundaries of planning units.

Land sea-connection via plume modelling

Coastal marine dynamics are highly complex, and without the high resolution spatial and temporal data needed to run complex numerical ocean circulation models, many studies have opted to use simpler methods to define the marine areas most likely to be impacted by terrestrial influences (Halpern et al. 2008; Schill and Raber 2009; Burke and Reytar 2011). To this end, we applied an existing plume model (Halpern et al. 2008) for those rivers with values above 5e9L/yr (to better align with global plume data developed in (Halpern et al. 2008), and to account for natural runoff). We spatially calculated the accumulated sediment from the NSPECT output at each river mouth for each scenario (see Appendix 2 for full details). A simple linear regression model was used to fit the distance of a plume per the discharge in the statistical computing software, R; the resulting function was applied to calculate the plume distance from river mouths.

Restorf Island, Kimbe, PNG © Nate Peterson/ The Nature Conservancy

5. CONSERVATION PRIORITIES

We explored a range of Marxan scenarios to demonstrate the changes in priorities depending upon connectivity and other settings (see Appendix 4 for list of scenarios). The final map of conservation priorities reflects the targets and connectivity settings discussed above, the conservation features and targets identified and reviewed during workshops held with CEPA, and revisions to priorities and features as identified during workshops held with experts (Appendix 3).

Marxan provides a range of good spatial solutions that meet the defined conservation objectives. Therefore, the selection frequency across runs can be interpreted as the extent to which there are spatial options for meeting objectives. Those areas with very high selection frequency are essential for meeting targets, whereas those with lower selection frequency are likely to be interchangeable with other options in the landscape. A map of selection frequency can be used to evaluate possible options within a region for meeting targets. In contrast, any one Marxan solution can be used as a firm road map. To meet the land-sea objectives set for this assessment approximately 20% of land and sea must be protected. We provide the selection frequency map (see Figure 4). This can be used as a road map for guiding local assessment of possible conservation priorities for further assessment and management planning. A range of conservation strategies will likely be needed (e.g. declaration of national parks, negotiation of locally managed areas, offsets) in any one conservation priority area to achieve protection and management of the area based on local context.

Given that approximately 20% of PNG's land and sea-scape is identified as conservation priorities, CEPA will have to schedule activities to further assess and implement individual conservation actions. One possible mechanism for scheduling areas for priority is by identifying large priority areas, which are therefore possible candidates for national parks or national government management and resourcing, and further stratify these across realms (terrestrial or marine) and identify those that have also been previously identified in other assessments as high priority. We show the map of priorities that meet these criteria in Figure 5 (~top 10 priority areas by size across realms: terrestrial, marine, terrestrial/marine (i.e. coastal priorities with joint protection required across terrestrial and marine zones) ensuring that they align with existing conservation assessments). This set of priorities was used to stimulate discussion with CEPA and experts about how to identify a final set of priority areas to be treated as top priorities for implementation. It was the foundation for the discussions had at the expert review workshop and stimulated the identification of 81 Areas of Interest (AOI) (see Figure 6).

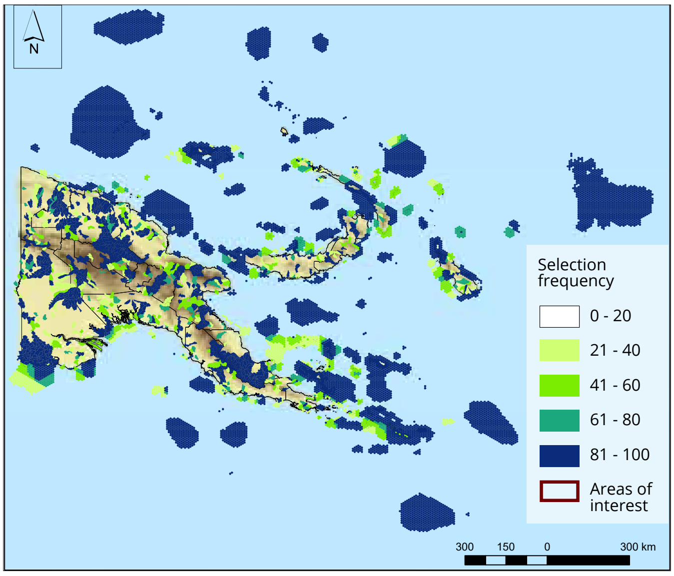


Figure 4: Final conservation priorities (selection frequency). The map of selection frequency indicates the extent to which there are spatial options for meeting conservation targets. Areas with high selection frequencies are essential to meeting targets while lower selection frequencies indicate that there are spatial options available

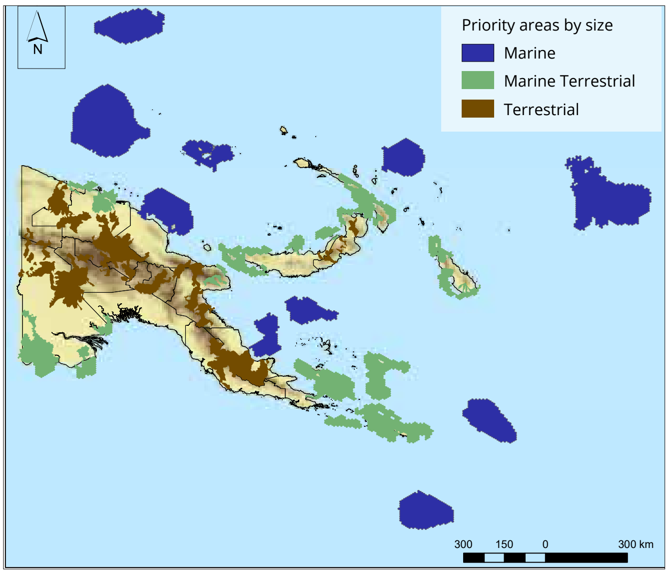


Figure 5: One possible set of priority areas for further assessment (based on size and concurrence with other assessments (e.g. WHA)

A review workshop was undertaken by CEPA November 2016 (see Appendix 3 for workshop details). During this workshop a list of 81 areas of interest were identified (Figure 6). This list can be used in conjunction with further data and research by CEPA to create a final shortlist of areas to focus on for immediate action. These 81 areas are being treated as the interim top priorities until further refinement to ~30 areas is finalised. A list of key values for the priority areas have been summarized in factsheets. Example factsheets from New Britain are presented in Appendix 5. New Britain was identified as a priority for producing and testing these factsheets as there are a number of activities being funded by or undertaken in collaboration with CEPA in New Britain that would benefit from use and piloting of these planning products.

A set of areas of interest to be scheduled for immediate further investigation and implementation create a tangible set of short term conservation priorities for CEPA to action. However, these areas should be used in conjunction with the map of selection frequency to ensure that other areas with smaller priority areas are not neglected. Furthermore, as areas are implemented, or conversely as areas are converted to alternative uses, data should be updated and priorities revised. CEPA staff need to have the capacity and access to interact with the data set to explore alternative options for regional and local conservation planning. This is particularly important as knowledge and on-ground circumstances change. This capacity is critical to adaptive planning.

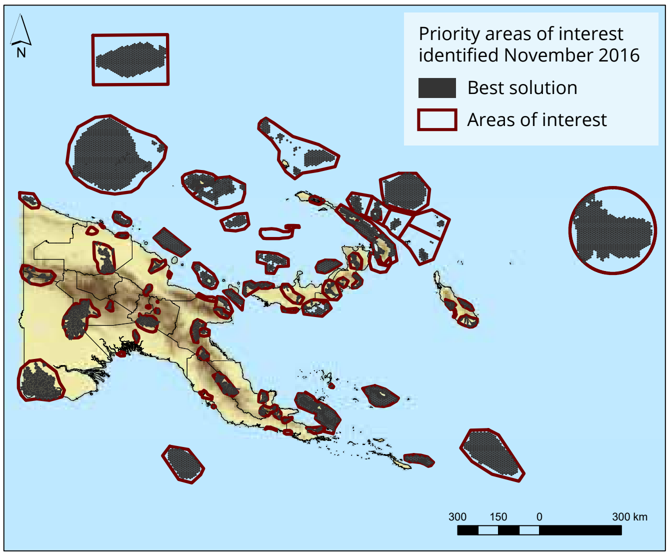


Figure 6: Final Priority Areas of Interest - areas identified through the expert review workshop intersected with priority areas from the marxan land-sea analysis. These are priority areas for further assessment. A subset of the Areas of Interest (A and A1 lists, appendix 3) were identified that are considered critical for short term action.

Local value mapping workshop, East New Britain, PNG © Cosmas Apelis/ The Nature Conservancy

Tree Kangaroo, PNG © Matt West/ Tenkile Conservation Alliance

6. CONSERVATION STRATEGIES

There are a range of conservation strategies that can be used to protect these conservation priorities that range from legal mechanisms to informal community based arrangements to management planning and activities. The conservation strategies identified for any particular conservation priority should reflect the policy being developed by CEPA. Strategies would reflect further consultation with local stakeholders such as provincial government and local landholders.

POSSIBLE STRATEGIES INCLUDE LEGAL MECHANISMS AND NON-BINDING ARRANGEMENTS

Legal mechanisms may include protection categories such as IUCN categories, world heritage areas or other locally defined protected area classes. Informal arrangement such as local protection approaches may be culturally appropriate and more meaningful to local communities. These include arrangements such as Tabus and locally managed marine areas (LMMAs). It is worth noting that in a number of cases there is overlap between priorities arising from this assessment and recommendations of Hitchcock and Gabriel (2015) World Heritage Tentative Listed Sites in Papua New Guinea (PNG). There is the opportunity to integrate these sites which overlap in order to streamline further investigation and reserve selection and design.

Within the factsheets (see Appendix 5), overlap between conservation priority sites and world heritage tentative listed sites have been noted so that CEPA can capitalize upon these overlaps.

MANAGEMENT PLANNING

Within priority areas, in addition to protection strategies, management planning can also support implementing management actions. Planning includes identifying threats and opportunities for conservation. For example:

1. Planning for possible conflicts such as shipping lanes through priority areas or mines within conservation priorities and managing or mitigating possible incidents and leveraging companies working within these areas for offsets or funding conservation activities.
2. Sharing priorities with other departments and trying to integrate into their planning and approvals processes to avoid high impact developments within priority areas.
3. Sharing with districts and Local-Level Government areas (LLGs) to integrate into their land use planning.

The Tari Gap, PNG © Alison Green/ The Nature Conservancy

7. PLANNING PRODUCTS

MAPS

The final maps of the selection frequency displayed in Figure 4 will be produced in hard copy at the national and provincial scale.

DIGITAL DATA

The data that was used for the priority setting has been provided as a set of ArcGIS databases to CEPA. These can be integrated into assessment processes to better understand why individual areas are priorities (e.g. similar summaries can be produced for all priority areas based on these data — see Appendix 5 for sample factsheets).

FACTSHEETS

Factsheets for the Areas of Interest (see Figure 6) summarize the values present in each priority area (Appendix 5). These factsheets can help guide management planning for these areas, identifying values for declaring protected area status or communicating values with stakeholders (e.g. provincial government or local communities), or assessing possible impacts of developments.

Pink Anemone Fish, Kimbe Bay, PNG © Vanessa Adams/University of Queensland

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APPENDICES

APPENDIX 1: DATA

TERRESTRIAL OBJECTIVES

Land Systems

Land Systems are areas or groups of areas throughout which there is a recurring pattern of topography, vegetation, and soils at a scale detectable from air photography (Christian & Stewart 1953). This study adopted the land systems of PNG (Bellamy & McAlpine 1995). Its upland land systems are characterized by distinctive topography and bedrock type. Lowland land systems are characterized by their distinctive terrain form and hydrology (Sheppard & Saxon 2008). Saxon and Sheppard (2008) matched the land systems of PNG (Bellamy & McAlpine 1995) with similar land units in Papuan provinces of Indonesia (RePPProT 1990). The resulting units provide uniform abiotic features mapped across the New Guinea archipelago.

Vegetation

A land-use land-cover classification for 2013 was derived by updating the Papua New Guinean Forestry Inventory Management System from 1996. The Forest Information Management System (FIMS) mapping provides the best available vegetation data for PNG. FIMS was based on the interpretation of SKAIPIKSA air photography taken in 1973–75 (Hammermaster and Saunders 1995). The 1:100,000 classification includes a total of 61 vegetation types including: 36 Forests, 6 Woodland, 3 Savanna, 3 Scrub, 11 Grasslands, 1 Mangrove and 6 Non Vegetation Types. Each polygon in the classification is attributed with one to four different vegetation types in the following proportions: 1 class (100%), 2 classes (65%, 35%), 3 classes (65%, 25%, 10%) and 4 classes (65%, 25%, 5%, 5%). In order to calculate the total amount of each vegetation type, areas of each vegetation type for each polygon were allocated in the amounts defined above.

Although this data represents the best available vegetation data for PNG, it is over 15 years old and does not account for deforestation and land-use change since 1996, which in some areas has been severe. We therefore updated the FIMS vegetation data using Landsat 7 ETM+ images using on-screen digitization to distinguish forested, urbanized, and cultivated land at 100 m as well as landcover data from the Roundtable on Sustainable Palm Oil (RSPO). We then further updated this layer using the Global Forest Watch dataset (also known as the Hansen forest cover data) (Hansen et al. 2013) to remove any areas that had 0% forest cover in 2013. We further developed a discounting factor that identified any recently disturbed/deforested areas in PNG and discounted features that were either degraded, or were non-target land-cover types, such as bare land, agriculture, urban, forestry, and mining.

Fauna

Species used in this analysis included 170 rare or restricted range endemic species (RREs) including Bird of Paradise (10), Tree Kangaroos (12), Reptiles and Amphibians (123), and Mammals (25) (see A1 Table 1). These data were collected and compiled by Allen Allison of the Bishop Museum. Restricted range endemic species data from the Bishop museum represents the best estimates of the current distribution of each species using minimum convex polygons. Islands support 37% of all IUCN critically endangered species (Jones et al. 2016). We used the IUCN Red List species range maps available for download for terrestrial mammals, reptiles and amphibians and included all species that were critically endangered and endangered (total 28 including mammals (27) and amphibians (1).

Climate Change

To account for future climate threats to land systems and vegetation, we targeted climate refugia in our analyses. Projected refugia in the year 2100 were previously identified under climate scenario A2 (Nakicenovic & Swart 2000), using the HadCM3 general circulation model (GCM) (Gordon et al. 2000). HadCM3 is a highly climateresponsive GCM and scenario A2 assumes limited climate mitigation action. These choices were made in order to develop a set of protected areas that would include refugia under severe future conditions, a precautionary approach given the uncertainty around the likely effectiveness of climate mitigation. In order to preferentially identify conservation areas in locations of likely climate change refugia, each planning unit was assigned a probability that corresponded to the expected extent of climate change. A high probability meant that a planning unit was less likely to act as a climate change refugia, whereas those planning units with a lower probability had a higher chance of being refugia. To assign probabilities, the climate change surface developed by Saxon et al. (2005, 2008) was normalized to a scale from 0 to 1, with 1 being assigned to the pixel that was expected to experience the greatest change in climate, across the entire island of Papua (i.e., including theIndonesian portion). Within each planning unit, probabilities were averaged across pixels, to give a mean probability of change per planning unit.

Cleaner Shrimp, Kimbe Bay, PNG © Nate Peterson/ The Nature Conservancy

A1 Table 1: List of rare or restricted range endemic species (RRE) and threatened species (Threatened) included in the assessment

Species	Type
Albericus exclamitans	RRE
Albericus fafniri	RRE
Albericus gudrunae	RRE
Albericus rhenaurum	RRE
Albericus sanguinopictus	RRE
Albericus siegfriedi	RRE
Albericus swanhildae	RRE
Antaresia maculosa	RRE
Aphantophryne minuta	RRE
Aphantophryne pansa	RRE
Aphantophryne sabini	RRE
Aproteles bulmerae	RRE, Threatened
Astrapia mayeri	RRE
Astrapia rothschildii	RRE
Astrapia stephaniae	RRE
Austrochaperina archboldi	RRE
Austrochaperina brevipes	RRE
Austrochaperina polysticta	RRE
Barygenys cheesmanae	RRE
Barygenys flavigularis	RRE
Barygenys maculata	RRE
Barygenys parvula	RRE
Batrachylodes gigas	RRE
Callulops eremnosphax	RRE
Callulops glandulosus	RRE
Callulops marmoratus	RRE
Callulops omnistriatus	RRE
Callulops sagittatus	RRE
Chelonia mydas	Threatened
Choerophryne allisoni	RRE
Choerophryne burtoni	RRE
Choerophryne siegfriedi	Threatened
Conilurus penicillatus	RRE
Cophixalus aimbensis	RRE
Cophixalus ateles	RRE
Cophixalus bewaniensis	RRE
Cophixalus cryptotympanum	RRE
Cophixalus cupricarenus	RRE
Cophixalus daymani	RRE
Cophixalus interruptus	RRE
Cophixalus iovaorum	RRE
Cophixalus kaindiensis	RRE
Cophixalus kethuk	RRE
Cophixalus linnaeus	RRE
Cophixalus melanops	RRE
Cophixalus misimae RRE	RRE
Cophixalus nubicola	RRE
Cophixalus phaeobalius	RRE
Cophixalus pulchellus	RRE
Cophixalus sisyphus	RRE
Cophixalus sphagnicola	RRE
Cophixalus tagulensis	RRE
Cophixalus timidus	RRE
Cophixalus tomaiodactylus	RRE
Cophixalus verecundus	RRE
Copiula pipiens	RRE
Cryptoblepharus furvus	RRE
Cryptoblepharus richardsi	RRE
Ctenotus robustus	RRE
Ctenotus spaldingi	RRE
Cyrtodactylus capreoloides	RRE
Cyrtodactylus derongo	RRE
Cyrtodactylus klugei	RRE
Cyrtodactylus louisiadensis	RRE
Cyrtodactylus murua	RRE
Cyrtodactylus robustus	RRE
Cyrtodactylus tripartitus	RRE
Dactylopsila tatei	RRE, Threatened
Dendrolagus cf. scottae	RRE
Dendrolagus dorianus	RRE
Dendrolagus dorianus notatus	RRE
Dendrolagus dorianus stellarum	RRE
Dendrolagus goodfellowi	RRE, Threatened
Dendrolagus goodfellowi buergersi	RRE
Dendrolagus goodfellowi goodfellowi	RRE
Dendrolagus goodfellowi pulcherrimus	RRE
Dendrolagus inustus	RRE
Dendrolagus lumholtzi	RRE
Dendrolagus matschiei	Threatened
Dendrolagus notatus	Threatened
Dendrolagus pulcherrimus	Threatened
Dendrolagus scottae	RRE, Threatened
Dendrolagus spadix	RRE
Diporiphora bilineata	RRE
Dorcopsis atrata	RRE
Echymipera davidi	RRE
Echymipera echinista	RRE
Epimachus fastuosus	RRE
Eretmochelys imbricata	Threatened
Hydromys ziegler	RRE
Hylophorbus picoides	RRE
Hylophorbus proekes	RRE
Hylophorbus rainerguentheri	RRE

Hylophorbus richardsi	RRE
Hypsilurus ornatus	RRE
Hypsilurus schoedei	RRE
Leiopython bennetti	RRE
Leiopython huonensis	RRE
Leptomys signatus	RRE
Liophryne magnitympanum	RRE
Liophryne similis	RRE
Lipinia albodorsalis	RRE
Litoria albolabris	RRE
Litoria becki	RRE
Litoria bulmeri	RRE
Litoria chrisdahli	RRE
Litoria contrastens	RRE
Litoria dorsivena	RRE
Litoria eschata	RRE
Litoria flavescens	RRE
Litoria hilli	RRE
Litoria huntorum	RRE
Litoria majikthise	RRE
Litoria mucro	RRE
Litoria oenicolen	RRE
Litoria ollauro	RRE
Litoria robinsorae	RRE
Litoria rubrops	RRE
Litoria singadanae	RRE
Macgregoria pulchra	RRE
Mantophryne axanthogaster	RRE
Mantophryne infulata	RRE
Mantophryne louisiadensis	RRE
Melomys arcium	RRE
Melomys matambuai	Threatened
Microhydromys musseri	RRE
Mixophyes hihihorlo	RRE
Myoictis leucura	RRE
Myoictis wavicus	RRE
Myotis macropus	RRE
Nactus acutus	RRE
Nactus pelagicus	RRE
Nyctimystes avocalis	RRE
Nyctimystes daymani	RRE
Nyctimystes kuduki	RRE
Nyctimystes obsoletus	RRE
Nyctimystes tyleri	RRE
Nyctimystes zweifeli	RRE
Nyctophilus bifax	RRE
Oreophryne geminus	RRE
Oreophryne kampeni	RRE
Oreophryne terrestris	RRE
Otomops papuensis	RRE
Otomops secundus	RRE
Oxydactyla coggeri	RRE
Paradisaea guilielmi	RRE
Paradisaea raggiana	RRE
Paradisaea rudolphi	RRE
Paraleptomys rufilatus	Threatened
Paramelomys gressitti	Threatened
Parotia lawesii	RRE
Parotia wahnesi	RRE
Peroryctes broadbenti	Threatened
Petaurus abidi	RRE, Threatened
Phalanger lullulae	RRE, Threatened
Phalanger matanim	RRE, Threatened
Pharotis imogene	RRE, Threatened
Pherohapsis menziesi	RRE
Platymantis bufonulus	RRE
Platymantis caesiops	RRE
Platymantis macrops	RRE
Platymantis mamusiorum	RRE
Platymantis nakanaiorum	RRE
Platymantis sulcatus	RRE
Pogonomys championi	RRE
Pogonomys fergussoniensis	Threatened
Pteralopex anceps	Threatened
Pteralopex flanneryi	Threatened
Pteropus scapulatus	RRE
Rattus vandeuseni	Threatened
Saccolaimus flaviventris	RRE
Solomys ponceleti	Threatened
Solomys salebrosus	Threatened
Sphenomorphus louisiadensis	RRE
Sphenomorphus microtympanus	RRE
Sphenomorphus transversus	RRE
Spilocuscus rufoniger	Threatened
Taphozous australis	RRE
Thylogale calabyi	Threatened
Thylogale lanatus	Threatened
Toxicocalamus holopelturus	RRE
Toxicocalamus misimae	RRE
Typhlops fredparkeri	RRE
Typhlops hades	RRE
Typhlops mcdowelli	RRE
Varanus telenesetes	RRE
Xenobatrachus huon	RRE
Xenobatrachus subcroceus	RRE
Xeromys myoides	RRE
Zaglossus bartoni	Threatened

RRE data under license from Bishop Museum, Threatened species downloaded from IUCN Red List of Threatened Species.

MARINE OBJECTIVES

Biophysical data

Data on 19 seafloor habitats from the GRID-ARENDAL Geomorphic Seafloor Features database (Harris et al 2014) were used, describing broad marine habitat classes, from abyssal plains to shallow shelf regions existing in PNG's EEZ. These features were further divided by depth class using General Bathymetric Chart of the Oceans (GEBCO) with 30 arc-second resolution (the GEBCO 08 Grid, version 20090202, www.gebco.net). This digital bathymetry was generated by combining ship depth soundings, with the interpolation between the sounding points being guided by satellite gravity data (Becker et al., 2009). This resulted in the biophysical data being stratified into 7 depth classes from shelf (<200m) to below 6000m.

Coastal Data

The most detailed classification for coral reefs available for PNG were used, provided by the Millenium Coral Reef Mapping Project (MCRMP) (see Andrefout and Hamel 2014 for more details). We used Level 5 classifications which detail any given reef polygon based on a combination of depth and exposure as well as identified geomorphological characteristics for a total of 333 different classified reef habitats. To the southwest of the Gulf of Papua, in regions not included in the scientific boundary of the Coral Triangle, we used data from the Global Distribution of Coral Reefs 2010 (UNEP-WCMC) in addition to the MCRMP data. While not classified as coral reefs under the MCRMP, unclassified polygons still provide coarse information on shallow habitats present in the region. These polygons were split into inshore and offshore shallow bathymetric features and were treated as unique features to represent in the analysis.

Mangroves are important ecosystems to be represented across PNG. Not only do they provide important ecosystem services through coastal protection and filtering run-off from the land, they are also important nursery grounds for marine species. Global mangrove distribution data was obtained from UNEP World Conservation Monitoring Centre (UNEP-WCMC) who compiled distributional data in collaboration with the International Society for Mangrove Ecosystems (ISME).

To account for other important benthic habitats for which we did not have distributional data (i.e. sand, rock, mud bottoms), a non-reef shelf habitat class for the remaining shelf areas not-classified as reefs and extending out to the continental slope (< 200m) was also used.

MARINE FAUNA (SPECIAL FEATURES)

Seabirds and Shorebirds

We included Important Bird Areas (IBAs) in PNG as identified by Birdlife International (www.birdlife.org/action/science/sites/; Trainor et al. 2007). These are globally important habitat for the conservation of bird populations and are based partly on the location of threatened and endemic species, and so relate to conservation and representation objectives. Their limitation is that they are mapped at a broad scale. The coverage of IBAs were sourced from Birdlife International (Trainor et al. 2007), with three proposed IBAs found in Papua New Guinea for: Beck's Petrels (Pseudobulweria becki), Heinroth's shearwaters (Puffinus heinrothi), and Streaked Shearwaters (Calonectris leucomelas). Additional data on important sites for migratory shorebirds was obtained from Wetlands International, who have identified 3 important areas for the conservation of migratory shorebirds in PNG. These include the Red-necked Phalarope (Phalarope lobatus), Brown Noddy (Anous stolidus), and the Greater Sand Plover (Charadrius leschenaultia) (Bamford et al 2008 Migratory Shorebirds of EAAF. Wetlands International). These areas were hand-digitized and included as special features in the analysis.

Marine Megafauna

Data describing critical sites for migratory turtles was obtained from WWF-Indonesia for all of PNG. This data identifies point locations of either nesting, foraging, or other identified critical habitat for green turtles (Chelonia mydas) and leatherback turtles (Dermochelys coriacea). The IUCN Red List of Threatened Species have identified green turtles as endangered and requiring conservation action (Seminoff 2004), whilst leatherback turtles are listed as vulnerable (Wallace 2013). In alignment with the requirements of the CBD, the PNG government has determined that threatened

species should be afforded protection throughout the region. To meet these requirements, we identified catchments of 30 km radius around important turtle habitat to incorporate the typical spatial extent of beaches and foraging areas (Beger et al. 2013). Data on

Green Turtle Hatchling, PNG © Vanessa Adams/ University of Queensland

important areas for blue whales (Balaenoptera musculus) was obtained from cetacean experts and identifies critical breeding areas for the species (Ben Kahn, Pers. Comm.). The International Whaling Commission granted protection to blue whales in 1966, however these species are still listed as Endangered by the IUCN (Reilly et al 2008) due to dramatic population reduction from historic commercial whaling.

Spawning Aggregations

Protecting spawning aggregation sites is important to maintain regional larval supplies, and has been effectively demonstrated in Melanesia and Micronesia, where fish biomass increased up to 10 fold after fishing ceased (Golbuu & Friedlander 2011; Hamilton et al. 2011). In this analysis we used spawning aggregation data for12 fish families including groupers (Serranidae), snappers (Lutjanidae) and emperors (Lethrinidae), under license from the Society for the Conservation of Reef Fish Aggregations (SCRFA) (Sadovy de Mitcheson et al. 2008). To represent fish spawning aggregations, we aim to protect all known active and historical aggregation site locations. As transient spawning aggregations may draw individuals from a large catchment, we identified catchments as reef areas within a 20 km radius from known fish spawning aggregation coordinates, a number representative for the home range of large spawners such as Plectropomus areolatus or Epinephelus polyphekadion (Beger et al. 2013; Green et al 2014). We designated all shelf and slope areas falling within the 20km buffer as associated spawning aggregation habitat. Because of variability in the data records of habitat associations and individual spawning aggregations, we did not distinguish between reefs and non-reef habitat.

While there are other important biogenic habitat found throughout PNG, such as seagrass, the resolution of the available data covering the extent of PNG was too coarse to be used for this analysis. Similarly, many of the global distributions for important threatened and endangered species in PNG are only available in resolutions too coarse to be useful at the scale of this analysis. This includes the distribution on dugongs and humphead wrasse, which are highlighted as species of concern by conservation groups working in the Coral Triangle.

A1 Table 2: Terrestrial data

Previous plan use	Target	Data Type	File Name	Type	Description	Credits	Year Updated	Access and use limitations	Resolution	Reference system/ projection	Extent	Websource
Terrestrial PoWPA 2010	10–20%	Biodiversity	FIMS - Vegetation	Polygon	FIMS Data Layer - vegetation data from FIMS This veg layer has been amended to include text descriptions of each vegetation class	Forestry Inventory Management System PNG	1996	No known limitations. However any user of this data would be wise to recognize that this data represents conditions in 1996 and has not been maintained since.	Variable	GCS WGS 1984	PNG	
None	N/A	Biodiversity	Hanson forest cover	Raster	Forest and deforested (0,1)	Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S., Tyukavina, A., Thau, D., Stehman, S., Goetz, S., Loveland, T., 2013. High-resolution global maps of 21st-century forest cover change. Science 342, 850–853	2013	Open-source	0.00025 x 0.00025	GCS WGS 1984		
Terrestrial PoWPA 2010	10–20%	Biodiversity	Landsystems_New_Guinea	Polygon	Land systems v1 (original lines) This dataset has two input datasets. 1. PNGRIS 2. REPPPROT	Bryan JE and Shearman PL 2008 Papua New Guinea Resource Information System Handbook 3rd ed. University of Papua New Guinea. Port Moresby.	2008	Acknowledge data source	Variable	GCS WGS 1984	PNG	
None	N/A	Biodiversity	png_gc_adg_1.shp	Polygon	Global FAO landcover - PNG national	FAO	Unknown	Open-source	Variable	GCS WGS 1984	PNG	www.fao.org/geonetwork

A1 Table 2: Terrestrial data *continued*

Previous plan use	Target	Data Type	File Name	Type	Description	Credits	Year Updated	Access and use limitations	Resolution	Reference system/ projection	Extent	Websource
None	N/A	Biodiversity	Bird_marine	Polygon	Important Bird Areas (IBA) for seabird, and important areas for migratory shorebirds, including wetlands (digitized from Bamford et al 2008)	Birdlife International, (2012), 'Marine IBA Atlas', Accessed 10/10/2014.. Bamford, M.J., Watkins, D.G., Bancroft, W., Tischler, G. and Wahl, J. (2008) Migratory shorebirds of the East Asian-Australasian Flyway: Population Estimates and Important Sites. Wetlands International, Oceania, Canberra	2014	Open-source	Variable	WGS 1984 World Cylindrical Equal Area	PNG	http:// datazone. birdlife. org/site/ mapsearch
Terrestrial PoWPA 2010	50%	Biodiversity	Fauna_endemic	Polygon	RRE reptiles and amphibians and mammals	(Allen Allison — Bishop Museum		Open-source				
None	N/A	Climate	Av_annual_precip_plate1	Raster	Annual average precip mm	Fischer, G. et al. (2002) Global Agro-Ecological Assessment for Agriculture in the 21st Century: Methodology and Results, International Institute for Applied Systems Analysis and Food and Agriculture Organization of the United Nations	2002	Open-source	Very coarse	GCS WGS 1984		http:// webarchive. iiasa.ac.at/ Research/ LUC/SAEZ/
None	N/A	Climate	prec_310.tif	Raster	Worldclim Rainfall raw data for eastern region of PNG	Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978	2005	Open-source	30 arc seconds	GCS WGS 1984	PNG East	www.worldclim.org/formats

None	N/A	Climate	prec_311.tif	Raster	Worldclim Rainfall raw data for western region of PNG	Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978	2005	Open-source	30 sec resolution/1 square km	GCS WGS 1984	PNG East	www.worldclim.org
None	N/A	Climate	prec_12months_average	Raster	Worldclim Rainfall averaged for 12 months from worldclim Raster	Peterson, N. (2014), 'Cataloguing PNG's protected areas', Technical report for PNG DEC	2005	Open-source	30 sec resolution	WGS84	PNG	www.worldclim.org
PoWPA 2010	Used	Conservation	MA_PNG_2014_April10	Polygon	Latest PA designations for PNG	Peterson, N. (2014), 'Cataloguing PNG's protected areas', Technical report for PNG DEC	2014	Open-source	Variable	Various	PNG	
None	N/A	Geophysical	DEM_100res.tif	Raster	The PNG 90m DEM is a composite of the NASA SRTM data and a DEM created by UPNG using countour lines, points and drainage enforcement. When the SRTM data has a far better delineation of topography, it also has many gaps in the data due to radar shadows. The composite data set uses the UPNG DEM to fill these gaps	Phil Shearman, UPGS	2009	Unknown	90m	AGD, GCS WGS 1984	PNG	
None	N/A	Geophysical	max_evap_mns	Raster	Evaporation, Maximum Evaporation, 1979–1999, Evaporation	World Resources Institute (WRI)	1999	Open-source	Very coarse	GCS Clarke_1966	PNG	

A1 Table 2: Terrestrial data *continued*

Previous plan use	Target	Data Type	File Name	Type	Description	Credits	Year Updated	Access and use limitations	Resolution	Reference system/ projection	Extent	Websource
None	N/A	Geophysical	maxsoilmoist	Raster	Grid with estimated maximum available soil moisture in mm/m. Information with regard to maximum available soil moisture was calculated from the "Derived Soil Properties" of the "Digital Soil Map of the World" which contains raster information on soil moisture in different classes	FAO	2009	Open-source	5 arc-minute	GCS WGS 1984	PNG	www.fao.org/geonetwork/srv/en/main.home
None	N/A	Geophysical	PapuaNew-Guinea57	Raster	Pantropic biomass. National dataset of Aboveground Live Woody Biomass density at spatial resolution of circa 500m derived from field/ LiDAR(GLAS)/MODIS. The pixel values are in megagrams (Mg) of Aboveground Live Woody Biomass per Hectare (Mg/Ha)	A. Baccini, S J. Goetz, W.S. Walker, N. T. Laporte, M. Sun, D. Sulla-Menashe, J. Hackler, P.S.A. Beck, R. Dubayah, M.A. Friedl, S. Samanta and R. A. Houghton. Estimated carbon dioxide emissions from tropical deforestation improved by carbondensity maps. 2012 Nature Climate Change, www.nature.com/nclimate/journal/v2/n3/full/nclimate1354.html	2012	Open-source	500 x 500m	WGS 84	PNG	www.whrc.org/data
None	N/A	Geophysical	png_gc_adg_1	Polygon	landcover FAO 2009. Vector format of EU commission global land cover	FAO 2009	2009	Open-source	Variable	GCS WGS 1984	PNG	www.fao.org/geonetwork/srv/en/

None	N/A	Geophysical	TAXGWRB_1km	Raster	SoilGrids1km is a collection of updatable soil property and class maps of the world at a relatively coarse resolution of 1km produced using state-of-the-art model-based statistical methods: 3D regression with splines for continuous soil properties and multinomial logistic regression for soilclasses	Hengl T, de Jesus JM, MacMillan RA, Batjes NH, Heuvelink GBM, et al. (2014) SoilGrids1km — Global Soil Information Based on Automated Mapping. PLoS ONE 9(8): e105992. doi:10.1371/ journal.pone.0105992 ISRIC — World Soil Information, 2013. SoilGrids: an automated system for global soil mapping	2014	Open-source. This product incorporates data from the HydroSHEDS database which is © World Wildlife Fund, Inc. (2006–2013) and is under license. WWF has not evaluated the data as altered and incorporated within and therefore gives no warranty regarding its accuracy, completeness, currency or suitability for any particular purpose. Portions of the HydroSHEDS database incorporate data which are the intellectual property rights of © USGS (2006–2008), NASA (2000–2005), ESRI (1992–1998), CIAT (2004–2006), UNEP-WCMC (1993), WWF (2004), Commonwealth of Australia (2007), and Her Royal Majesty and the British Crown and are used under license	1km	GCS WGS 1984	Global	http:// soilgrids.org

A1 Table 2: Terrestrial data *continued*

Previous plan use	Target	Data Type	File Name	Type	Description	Credits	Year Updated	Access and use limitations	Resolution	Reference system/ projection	Extent	Websource
None	N/A	Geophysical	hybas_png_lev10_v1c.shp	Polygon	Hydrosheds. Watersheds for Papua New Guinea	Lehner, B., Grill G. (2013): Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes, 27(15): 2171–2186. Data is available at www. hydrosheds.org. C/- Simon Linke, Griffith University	2013	HydroBASINS is covered by the same License Agreement as the HydroSHEDS database, which is available at www. hydrosheds.org. For all regulations regarding license grants, copyright, redistribution restrictions, required attributions, disclaimer of warranty, indemnification, liability, waiver of damages, and a precise definition of licensed materials, please refer to the License Agreement. By downloading and using the data the user agrees to the terms and conditions of the License Agreement	Variable	GCS WGS 1984	PNG	www.hydrosheds.org/download
None	N/A	Geophysical	hydrosheds-elevation_cond	Raster	Hydrosheds. Conditioned elevation grids	Lehner, B., Verdin, K., Jarvis, A.(2008): New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89(10): 93–94.C/- Simon Linke, Griffith University	2008	Open-source. Covered by the same License Agreement as the HydroSHEDS database, which is available at: www.hydrosheds.org	3sec resolution	GCS WGS 1984	Global	www.hydrosheds.org/download
None	N/A	Geophysical	hydrosheds-DEM	Raster	Hydrosheds. Void-filled elevation grids	Lehner, B., Verdin, K., Jarvis, A.(2008): New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89(10): 93–94. C/- Simon Linke, Griffith University	2008	Open-source. Covered by the same License Agreement as the HydroSHEDS database, which is available at: www.hydrosheds.org	3sec resolution	GCS WGS 1984	Global	www.hydrosheds.org/download

None	N/A	Geophysical	hydrosheds-drainage	Raster	Hydrosheds. Flow directions	Lehner, B., Verdin, K., Jarvis, A.(2008): New global hydrography derived from space-borne elevation ata. Eos, Transactions, AGU, 89(10): 93–94. C/- Simon Linke, Griffith University	2008	Open-source. Covered by the same License Agreement as the HydroSHEDS database, which is available at: www.hydrosheds.org	3sec resolution	GCS WGS 1984	Global	www.hydrosheds.org/download
None	N/A	Geophysical	hydrosheds-flowac	Raster	Hydrosheds. Flow accumulation	Lehner, B., Verdin, K., Jarvis, A. (2008): New global hydrography derived from space-borne elevation data. Eos, Transactions, AGU, 89(10): 93–94. C/- Simon Linke, Griffith University	2008	Open-source. Covered by the same License Agreement as the HydroSHEDS database, which is available at: www.hydrosheds.org	15sec resolution	GCS WGS 1984	Global	www.hydrosheds.org/download
None	N/A	Geophysical	hydrosheds-river	Raster	Hydrosheds. River network	Lehner, B., Verdin, K., Jarvis, A. (2008): New global hydrography derived from space-borne elevation data. Eos, Transactions, AGU, 89(10): 93–94. C/- Simon Linke, Griffith University	2008	Open-source. Covered by the same License Agreement as the HydroSHEDS database, which is available at: www.hydrosheds.org	15sec resolution	GCS WGS 1984	Global	www.hydrosheds.org/download
None	N/A	Geophysical	SoilErodibility_k.nc	Raster	Soil erodibility. K was estimated by Maina Mbui using the methods described in Nam et al paper. Soil data used as an input is based on the Harmonized World Soil Database HWSD Version 1.21 (www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/)	Re-analysed by Maina Mbui. Based on Nam et al 2003. Soil data used as an input is based on the Harmonized World Soil Database HWSD Version 1.21 [citation FAO/IIASA/ISRIC/ ISS-CAS/JRC, 2012. Harmonized World Soil Database (version 1.2). FAO, Rome, Italy and IIASA, Laxenburg, Austria.]	2014	HWSD is open-source	1km	GCS WGS 1984	Global	

A1 Table 2: Terrestrial data *continued*

Previous plan use	Target	Data Type	File Name	Type	Description	Credits	Year Updated	Access and use limitations	Resolution	Reference system/ projection	Extent	Websource
None	N/A	Regions	png_shp100	Polygon	STRM DEM. Single shape file for all of PNG (for Open N-Spect model)	Unknown	Unknown	Unknown	100m	GCS WGS 1984	PNG	
None	N/A	Regions	Boundary_provinces	Polygon	Polygons of province boundaries	Unknown	Unknown	Unknown	Variable	GCS WGS 1984	PNG	
Terrestrial PoWPA 2010	Used as cost	Social	census_2000_cu	Point	Census points — year 2000. Census pop of each ward for whole of PNG by total pop, total female, total male	Unknown	Unknown	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	
Terrestrial PoWPA 2010	Used as cost	Social	census_2000_districts	Polygon	District level census boundaries — Year 2000. Name, area, pop (tot, m,f), density, household size, traditional owner stuff	Unknown	Unknown	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	
Terrestrial PoWPA 2010	Used as cost	Social	census_2000_lig	Polygon	Local Level Government level census boundaries — Year 2000. Name, area, pop (tot, m,f), density, household size, traditional owner stuff	Unknown	Unknown	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	
Terrestrial PoWPA 2010	Used as boundaries	Social	census_2000_provinces	Polygon	Provincial level census boundaries — Year 2000. Name, area, pop (tot, m,f), density, household size,traditional owner stuff	Unknown	2000	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	
None	N/A	Social	Towns	Point	Towns in PNG. Town name, class, population (total, m,f), province	Unknown	Unknown	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	

None	N/A	Social	Capitals	Point	Capital towns of PNG	Unknown	Un-known	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	
None	N/A	Social	population	Point	Population of major towns	Unknown	Un-known	Unknown	Variable	WGS 1984 World Cylindrical Equal Area		
None	N/A	Social	Roads	Polyline	Main roads across PNG	Unknown	Un-known	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	
None	N/A	Social	Schools	Point	Schools in PNG	Unknown	Un-known	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	
None	N/A	Threats	FIMS — Ex-treme Constraints	Polygon	FIMS Data Layer — Ex-treme constraints data from FIMS Extreme constraints: land of greater than 30 deg. slope or above 2400m altitude or comprising tower karst landform or whose area is more than 80% permanently or near permanently inundated	Forestry Inventory Management System PNG		No known limitations. However any user of this data would be wise to recognize that this data represents condi-tions in 1996 and has not been main-tained since	Variable	GCS WGS 1984	PNG	

A1 Table 2: Terrestrial data *continued*

Previous plan use	Target	Data Type	File Name	Type	Description	Credits	Year Updated	Access and use limitations	Resolution	Reference system/ projection	Extent	Websource
None	N/A	Threats	FIMS — Logged (1996)	Polygon	FIMS Data Layer — logged areas as of 1996	Forestry Inventory Management System PNG	1996	No known limitations. However any user of this data would be wise to recognize that this data represents conditions in 1996 and has not been maintained since	Variable	GCS WGS 1984	PNG	
None	N/A	Threats	FIMS — Proposed (1996)	Polygon	FIMS Data Layer — proposed logging concessions as of 1996	Forestry Inventory Management System PNG	1996	No known limitations. However any user of this data would be wise to recognize that this data represents conditions in 1996 and has not been maintained since	Variable	GCS WGS 1984	PNG	
None	N/A	Threats	FIMS — Serious Constraints	Polygon	FIMS Data Layer — Serious constraints Forests on land with 20–30 deg. slope and very high to high relief or land whose area has 50–80% permanent or near permanent inundation	Forestry Inventory Management System PNG	1996	No known limitations. However any user of this data would be wise to recognize that this data represents conditions in 1996 and has not been maintained since	Variable	GCS WGS 1984	PNG	
None	N/A	Threats	FIMS — Timber Concessions (1996)	Polygon	FIMS Data Layer — concessions data	Forestry Inventory Management System PNG	1996	No known limitations. However any user of this data would be wise to recognize that this data represents conditions in 1996 and has not been maintained since	Variable	GCS WGS 1984	PNG	
None	N/A	Threats	MRA_Mining_Tenements.gdb	Polygon	Mineral exploration leases (as at May 3 2013)	Mineral Resources Authority (MRA), Dept. of Environment & Conservation	2013	Unknown	Variable	GCS WGS 1984	PNG	
None	N/A	Threats	pngagst2011_56n-Merge_2	Polygon	Oil palm plots as delineated for the Gunarso et al. 2013 RSPO report titled "Oil palm and land use change in Indonesia, Malaysia and Papua New Guinea"	Gunarso et al. 2013 RSPO report "Oil palm and land use change in Indonesia, Malaysia and Papua New Guinea"	2010	Confidential, obtained via V Tulloch, license restrictions	Variable	GCS WGS 1984	PNG	

A1 Table 3: Marine data covering the extent of Papua New Guinea's EEZ

	Target	Data Type	File Name	Type Shape/ Raster	Description	Credits	Access and use limitations	Resolution	Reference system/ projection	Extent	Web-source
Marine PoWPA 2015	10 – 20%	Biodiversity	WCMC2010_clipPNG.shp	Polygon	Global distribution of coral reefs (2010). Shows the global distribution of coral reefs in tropical and subtropical regions. The most comprehensive global dataset of warm-water coral reefs to date, acting as a foundation baseline map for future, more detailed, work. This dataset was compiled from a number of sources by UNEP World Conservation Monitoring Centre (UNEP-WCMC) and the WorldFish Centre, in collaboration with WRI (World Resources Institute) and TNC (The Nature Conservancy). Data sources include the Millennium Coral Reef Mapping Project (IMaRS-USF and IRD 2005, IMaRS-USF 2005) and the World Atlas of Coral Reefs (Spalding et al. 2001)	UNEP-WCMC, WorldFish Centre, WRI, TNC (2010). Global distribution of coral reefs, compiled from multiple sources including the Millennium Coral Reef Mapping Project. Version 1.3. Includes contributions from IMaRS-USF and IRD (2005), IMaRS-USF (2005) and Spalding et al. (2001). Cambridge (UK): UNEP World Conservation Monitoring Centre Andréfouët S, Muller-Karger FE, Robinson JA, Kranenburg CJ, Torres- Pulliza D, Spraggins SA, Murch B. (2006). Global assessment of modern coral reef extent and diversity for regional science and management applications: a view from space. Proceedings of 10th International Coral Reef Symposium: 1732–1745	Open-source	Variable, minimum 30m from Millenium Coral Reef Mapping project inputs	WGS 1984	PNG	http://data.unep-wcmc.org/datasets/1
Marine PoWPA 2015	10 – 20%	Biodiversity	WC-MC-014-SeagrassPolygons2005.shp	Polygon	Global distribution of seagrass (2005). This dataset shows the global distribution of seagrasses, and is composed of two subsets of point and polygon occurence data. The data were compiled by UNEP World Conservation Monitoring Centre in collaboration with Dr Frederick T. Short (University of New Hampshire, USA)	UNEP-WCMC, Short FT (2005). Global distribution of seagrasses (version 3.0). Third update to the data layer used in Green and Short (2003). Cambridge (UK): UNEP World Conservation Monitoring Centre Green EP, Short FT (2003). World atlas of seagrasses. Prepared by UNEP World Conservation Monitoring Centre. Berkeley (California, USA): University of California. 332 pp. URL: https://archive.org/ details/worldatlasofseag03gree	Open-source	1:1,000,000	WGS 1984	PNG	http://data.unep-wcmc.org/datasets/7

A1 Table 3: Marine data covering the extent of Papua New Guinea's EEZ *continued*

	Target	Data Type	File Name	Type Shape/ Raster	Description	Credits	Access and use limitations	Resolution	Reference system/ projection	Extent	Web-source
Marine PoWPA 2015	10 – 20%	Biodiversity	seagrassCSIRO1_region_UTM56S.shp	Polygon	Seagrass distribution	CSIRO	Unknown	Variable	AGD 94	PNG	
Marine PoWPA 2015	50%	Biodiversity	Kahnblue-WhalesCritical Habi-tatWCEA.shp	Polygon	Blue whale critical habitats digitized by Ben Kahn	Kahn, B.,Vance-Borland, K., (2014), 'Marine Conservation Planning and the Offshore Oil & Gas and Deep-Sea Mining, and Shipping Industries in the Coral Triangle and South West Pacific: Large-Scale Spatial Analysis of the Overlap between Priority Conservation Areas with Marine Extraction Blocks and International Shipping Lanes', Technical Report prepared for WWF Australia, pp. 66	Unknown	Variable	WGS 1984 World Cylindrical Equal Area	PNG	
Marine PoWPA 2015	N/A	Biodiversity	wwf_turtle-buff30km_noland	Polygon	Leatherback and green turtles	WWF-Malaysia and seaturtle.org	Restricted	Variable	GCS WGS 1984	PNG	
Marine PoWPA 2015	N/A	Biodiversity	Bird_marine	Polygon	Important Bird Areas (IBA) for seabird, and important areas for migratory shorebirds, including wetlands (digitized from Bamford et al 2008)	Birdlife International, (2012), 'Marine IBA Atlas', Accessed 10/10/2014. Available from http://maps.birdlife.org/marineIBAs/default.html. Bamford, M.J., Watkins, D.G., Bancroft, W., Tischler, G. and Wahl, J. (2008) Migratory shorebirds of the East Asian-Australasian Flyway: Population Estimates and Important Sites. Wetlands International, Oceania, Canberra	Open-source	Variable	World_Mercator Cylindrical Equal Area	PNG	
Marine PoWPA 2015	N/A	Biodiversity	PoWPA_Marine_Ecoregions	Polygon	Ecoregions developed by PoWPA	Green A., Kertesz M., Peterson N., Retif S., Skewes T., Dunstan P., McGowan J., Tulloch V., Kahn, B., (2014), 'A Regionalisation of Papua New Guinea's Marine Environment', Technical report for PNG DEC, pp.19	Open-source	Variable	WGS 1984 World Cylindrical Equal Area	PNG	

Marine PoWPA 2015	N/A	Biodiversity	PoWPA_Marine_Bioregions	Polygon	Bioregions developed by PoWPA	Green A., Kertesz M., Peterson N., Retif S., Skewes T., Dunstan P., McGowan J., Tulloch V., Kahn, B., (2014), 'A Regionalisation of Papua New Guinea's Marine Environment', Technical report for PNG DEC, pp.19		Variable	WGS 1984 World Cylindrical Equal Area	PNG	
Marine PoWPA 2015	10–20%	Biodiversity	mangroves_diss	Polygon	Mangroves	Spalding, M.D., Blasco, F., Field C.D.,(Eds.) (1997a), 'World MangroveAtlas. Okinawa (Japan): International Society for Mangrove Ecosystems, Pp. 178. Spalding, M.D., Blasco, F., Field C.D., (1997b), 'Global distribution of mangroves (version 3). Compiled by UNEP-WCMC, in collaboration with the International Society for Mangrove Ecosystems (ISME)'. In Supplement to: Spalding et al., (1997a)), ' Cambridge (UK): UNEP World Conservation Monitoring Centre', URL: data.unep-wcmc.org/datasets/6	Open-source	Variable	WGS 1984	Global	
Marine PoWPA 2015	50%	Biodiversity	Spags_reef-shelfslope	Polygon	Spawning & Aggregation Sites (Society for the Conservation of Reef Fish Aggregations (SCRFA). This data cannot be shared	Sadovy de Mitcheson Y., Cornish A., Domeier M., Colin P.L., Russell M. & Lindeman K.C., (2008), 'A global baseline for spawning aggregations of reef fishes', Conservation Biology, vol. 22, pp. 1233–1244	Restricted	Variable	GCS WGS 1984	Global	

A1 Table 3: Marine data covering the extent of Papua New Guinea's EEZ *continued*

	Target	Data Type	File Name	Type Shape/ Raster	Description	Credits	Access and use limitations	Resolution	Reference system/ projection	Extent	Web-source
Marine PoWPA 2015	10–20%	Geophysical	GEBCO_30sec_SP	Raster	Bathymetry: 7 Depth Zones (GEBCO global 30 arc-second grid: IOC, IHO and BODC 2003)	IOC, IHO,BODC, (2003), 'Centenary Edition of the GEBCO Digital Atlas, published on CD-ROM on behalf of the Intergovernmental Oceanographic Commission and the International Hydrographic Organization as part of the General Bathymetric Chart of the Oceans', British Oceanographic Data Centre, Liverpool, UK	Open-source	30 arc seconds	GCS WGS 1984	Global	www.gebco.net/data_and_products/gridded_bathymetry_data
Marine PoWPA 2015	10–20%	Geophysical	PNG_Shelf_GEBCO	Raster	Bathymetry: 7 Depth Zones (GEBCO global 30 arc-second grid: IOC, IHO and BODC 2003)	IOC, IHO,BODC, (2003), 'Centenary Edition of the GEBCO Digital Atlas, published on CD-ROM on behalf of the Intergovernmental Oceanographic Commission and the International Hydrographic Organization as part of the General Bathymetric Chart of the Oceans', British Oceanographic Data Centre, Liverpool, UK	Open-source	30 arc seconds	GCS WGS 1984	PNG	www.gebco.net/data_and_products/gridded_bathymetry_data
Marine PoWPA 2015	10–20%	Geophysical	Grid Arendal	Raster, converted to shapefile	Oceanic geomorphological features: 19 classes (shelf, seamounts, abyssal plains) (GRID-Arendal: Harris et al., 2014)	Harris, P. T., Macmillan-Lawler, M., Rupp, J., & Baker, E. K. ,(2014), Geomorphology of the oceans', Marine Geology, vol. 352, pp. 4–24	Open-source	30 arc seconds	GCS WGS 1984	Global	
None	N/A	Geophysical	Marine_Feature_PointsAnno	Labels	Geomorphic features — labels	Unknown	Open-source	TNC	Various	PNG	
None	N/A	Geophysical	Marine_Feature_Points	Points	Geomorphic features — point location	Unknown	Open-source	TNC	Various	PNG	
Marine PoWPA 2015	Buffer / ignore	Protection	MA_PNG_2014_April10	Polygon	Latest MPA designations for PNG	Unknown	Open-source	TNC	Various	PNG	
Marine PoWPA 2015	10–20%	Threats	OffshoreMiningBlocks	Polygon	Mineral exploration leases (as at March 2014)	PNG Department of Environment and Conservation		Variable		PNG	
Marine PoWPA 2015	Overlaid after prioritisation	Threats	Offshore Blocks - Oil and Gas.shp	Polygon	Oil and Gas leases (as at March 2014)	PNG Department of Environment and Conservation		Variable		PNG	

Marine PoWPA 2015	10–20%	Threats	artisanal		Artisinal fishing data for area	Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R., (2008), 'A Global Map of Human Impact on Marine Ecosystems', Science, vol. 319 no. 5865, pp. 948–952	Open-source			Global		
Marine PoWPA 2015	Overlaid after prioriti-sation	Threats	shipping_poly		Shipping lane data for area. Use threshold	Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry , M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R., (2008), 'A Global Map of Human Impact on Marine Ecosystems', Science, vol. 319 no. 5865, pp. 948–952	Open-source			Global		
Marine PoWPA 2015	Avoid	Threats	Weighted_landings_cost_data.shp	Polygon	Cost Distribution based on Distance to 13 ports (higher cost near ports) and Landings data from 2008–2013	Various		Variable		Global		
Marine PoWPA 2015	Cost	Threats	Ports_13	Polygon	Ports	Various	Open-source	Variable		Global		

APPENDIX 2: TERRESTRIAL RUNOFF MODEL

We used the open-source version of the runoff simulation tool N-SPECT (Nonpoint Source Pollution and Erosion Comparison Tool) (Eslinger et al. 2005) in MapWindow GIS to simulate runoff and sediment discharge from watersheds. N-SPECT combines data on elevation, slope, soils, precipitation, land cover characteristics, as well as surface retention and abstraction (USDA 1986), to derive estimates of runoff, erosion and pollutant sources (nitrogen, phosphorous and suspended solids), and accumulation in stream and river networks. Data sources and transformations for N-SPECT parameterization are described below.

Elevation data

Hydrologically corrected DEM at 500 m resolution maps were downloaded from hydroSHEDS's website. N-SPECT utilizes DEM as an input factor where slope steepness (S) and slope length (L) that are derived from DEM are RUSLE parameters that adjusts erosion rates based on topography, assigning higher rates to longer or steeper slopes and lower rates to shorter or flatter ones.

Soil data

Soil data were downloaded from Version 1.1 of the Harmonized soil database of the world (see A1 Table 2). We derived two variables for the runoff model: (i) hydrologic soil group, where soils were classified into four hydrologic soil groups (A, B, C and D) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting (Nam et al. 2003); and (ii) soil erodibility factor (K-factor), representing soil's susceptibility to erosion by rainstorms as a function of sand, silt, clay and organic carbon concentration. The average integrated K-factor was determined for each pixel using reclassification processes (Maina et al. 2012).

Rainfall data

Annual monthly average, maximum and minimum precipitation data for 2013 were obtained from Worldclim at 30 arc-seconds resolution (~1 km), and resampled to 90 m resolution. These data were used to determine the average erosive force of rainfall for each pixel, calculated from monthly rainfall data using the Modified Fournier Index (Vrieling et al. 2010).

Land-use Land-cover (LULC) data

Land-use land-cover (LULC) data A LULC classification for 2013 was derived by updating the Papua New Guinean Forestry Inventory Management System from 1996. The Forest Information Management System (FIMS) mapping provides the best available vegetation data for PNG. FIMS was based on the interpretation of SKAIPIKSA air photography taken in 1973–75 (Hammermaster and Saunders 1995). The 1:100,000 classification includes a total of 59 vegetation types including: 36 Forests, 6 Woodland, 3 Savanna, 3 Scrub, 11 Grasslands, 1 Mangrove and 4 Non Vegetation Types. Each Polygon in the classification is attributed with one to four different vegetation types in the following proportions: 1 class (100%), 2 classes (65%, 35%), 3 classes (65%, 25%, 10%) and 4 classes (65%, 25%, 5%, 5%). In order to calculate the total amount of each vegetation type, areas of each vegetation type for each polygon were allocated in the amounts defined above.

Although this data represents the best available vegetation data for PNG, it is over 15 years old and does not account for deforestation and land-use change since 1996, which in some areas has been severe (Shearman report). We therefore updated the FIMS vegetation data using Landsat 7 ETM+ images using on-screen digitization to distinguish forested, urbanized, and cultivated land at 100 m as well as landcover data from the Roundtable on Sustainable Palm Oil (RSPO) — only developed attributes (see A2 Table 1). We then updated this layer using the Global Forest Watch data (Hansen et al. 2013) to remove any areas that had 0% forest cover in 2013. We further developed a discounting factor that identified any recently disturbed/deforested areas in PNG whereby forest cover was less than 50%. We then created a final 'degradation factor' using the Undisturbed Forest % parameter from FIMS, which describes amount of undisturbed forest (0=completely degraded to 100%=undisturbed), and updated this parameter using the discounting factor, to create the final LULC layer.

A2 Table 1: Disturbed habitats from RSPO data used to update FIMS data

Abbreviation	Habitat type	Description
DSF	Disturbed Swamp Forest	Forest featuring temporary or permanent inundation with evidence of logging, canals or small-scale clearing.
CPL	Crop Plantation	Large industrial estates planted to rubber (Hevea brasiliensis), typically greater than 100 hectares.
OPL	Oil Palm Plantation	Large industrial estates planted to Oil Palm (typically greater than 100 hectares); typically greater than 100 hectares.
TPL	Timber Plantation	Large industrial estates planted to timber or pulp species (typically greater than 100 hectares) (e.g. Gmelina sp., Paraserianthes falcataria, Acacia mangium); canopy cover is around 30–50%.
MTC	Mixed Tree Crops	Agroforestry, usually located 0.5–1 km of settlement or road; canopy cover between 5 and 60%; includes small-scale plantings of commercial species, such as rubber coffee, cocoa and citrus, as well as a broad class of fruit producing species as part of a home garden.
DCL	Dry Cultivation Land (upland field crops)	Open area characterized by herbaceous vegetation with evidence of being intensively managed for row crops or pasture; typically associated with human settlements.
MIN	Mining	Open area with surface mining activities.
BRL	Bare land	Bare rock, gravel, sand, silt, clay, or other exposed soil; includes recently cleared (deforested) areas, landscapes impacted by fire and portions of estates undergoing replanting procedures.

Runoff model

N-SPECT (Eslinger et al. 2005) utilizes a modified version of Revised Universal Soil Loss Equation (RUSLE) (Williams 1975) as follows:

Ep = SDRp *(Rp *Kp *SLp *Cp)

Where 'R' is the rainfall/runoff erosivity factor per pixel 'p', 'K' is the soil erodibility K-factor, 'SL' is the slope-length actor derived from the DEM, which adjusts erosion rates based on topography (Renard et al. 1997), and SDR is the sediment delivery ratio (Williams 1977), a measure of watershed response to upland erosion which enables the model to account for retention, abstraction, and transportation of eroded soil by streams.

SDR was determined from the established NSPECT model as follows:

SDR = 1.366 * 10–11 * DA-0.0998 * ZL0.3629 * CN5.444

Where 'DA' is the drainage area (km^2) for each grid cell, 'ZL' is the relief-length ratio (m/km) calculated as the elevation change along the downslope flow path divided by the distance between cells along the flow path, and 'CN' is a runoff curve number determined from the land cover grid and soil hydrologic group. The runoff curve number represent the infiltration capacity of the soil and range from 0 to 100, with 0 being no runoff and 100 indicating no infiltration.

Calculation of rainfall erosivity: The rainfall erosivity actor (R) represents the erosion potential caused by rainfall. It is defined as the long-term average of the product of total rainfall energy and the maximum 30-min intensity (I30) of rainstorms (Wischmeier and Smith, 1978; Renard et al., 1997). Determining I30 typically requires at least 20 years of pluviograph data, and therefore the calculation of the R factor may not be possible in many data-poor regions. Instead, monthly average, maximum and minimum precipitation data for 2013 was obtained from Worldclim at 30 arc-seconds resolution (~1 km), and reclassified to 90m resolution. This data was used to determine the average erosive force of rainfall for each pixel, calculated from monthly rainfall data using the Modified Fournier Index (Vrieling et al). MFI is calculated using the following equation:

MFI=1/P Σ pi2

where P is the average annual rainfall (mm), and pi is the average rainfall (mm) in month i.

Calculation of soil erodibility: The soil erodibility factor (K) represents an integrated average annual value of the total soil and soil-profile reaction to a large number of erosion and hydrologic processes (Wischmeier and Smith, 1978). The most widely used and frequently cited relationship to estimate the K factor is the soil erodibility nomograph (Wischmeier et al., 1971), by using relationships between five soil and soil-profile parameters: percent modified silt (0.002–0.1 mm), percent modified sand (0.1–2 mm), percent organic matter, and classes for structure and permeability. Tew (1999) developed a soil erodibility nomograph specific to Malaysia, on the basis of an unmodified soil erodibility nomograph and relative K values obtained from experimental work using a portable rainfall simulator. Tew's equation was used to calculate the K factor for PNG as:

K=1.0x10-4(12-OM)M1.14+4.5(s-3)+8(pe-2) 759

where K is the Soil erodibility factor (t/ha)*(ha.hr/MJ.mm), M is the (% silt + % very fine sand) * (100 - % clay), OM is the percentage of organic matter, s is the soil structure code, and pe is the permeability code.

Cover Management Factor: The Cover Management Factor (C) indicates the effect of vegetation on soil erosion rates (Renard et al., 1997). It is the ratio of soil loss of a specific land use to the corresponding soil loss under the condition of bare land (Renard et al., 1997). The amount of protective coverage provided by vegetation influences the soil erosion rate, with bare soils or continuously tilled land having a C value equal to 1, while well-protected soils with dense vegetation have a C value near 0. For example an annual crop with low soil cover such as young oil palm may have a high C factor, meaning that erosion is not much less than on bare soil. On the other hand, a dense cover crop, or for instance mature palm plantations where undergrowth has been allowed to remain, will have a lower C value, whilst natural rain forest may have a C value as low as 0.001, meaning that erosion is one hundredth and one thousandth as fast, respectively, as on bare soil under the same climate, soil and slope.

Cover Management Factors (C) have not been accurately determined for the land-uses of PNG using field tests and rainfall simulator studies. We therefore estimated C values on the basis of literature containing comparable land-uses from areas with similar geographic and physical processes (Rude et al 2015), consultation with experts (A2 Table 2). We further refined our C-cover estimates to ensure that soil loss rates matched those found in available literature, whereby forest and agriculture yield 0.001–5 and 13–40 t ha-1 yr-1 erosion respectively on flat terrain, and up to 400 t ha-1 yr-1 on sloping agricultural land.

A2 Table 2: Literature review of cover management factors used in previous run-off models

Land Cover	Cover management factor (C)								
	*1	*2	*3	*4	*5	*6	*7	*8	*9
Bare soil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Crops/cultivated land	0.4	0.1–0.8	0.05–0.18		0.1–0.6	0.38		0.02–0.2	0.1–0.3
Grassland	0.02–0.45	0.01	0.01		0.007–0.4	0.03		0.01	0.2
Forest, dense undergrowth/high cover	0.006–0.45	0.03		0.001	0.001	0.001	0.001	0.001–0.02	0.01
Forest, good undergrowth/ medium cover					0.003	0.36			
Forest/ woodland, patchy undergrowth/ low cover	0.01–0.45				0.006	0.39		0.3	
Mangroves/ swampland						0.01	0.04	0.001	0.01

Land Cover	Cover management factor (C)								
	*1	*2	*3	*4	*5	*6	*7	*8	*9
Oil palm		0.1–0.3				0.2		0.5	
Other plantations				0.1–0.9	0.1–0.3	0.2			
Patchy tree cover						0.42			
Shrubs					0.15	0.03–0.40	0.72		0.2
Urban high density						0.05		0.01	
Urban medium density						0.05–0.15			
Urban low density/ builtup rural					0.2	0.25		0.02	
Mining						1.00		1.00	1.00
Road						0.01			
Water	0							0	

1. FAO; 2. Roose (1977) — West Africa; 3. Margolis and Campos Filho, 1981 — Brazil; 4. El-Swaify et al. (1982) — various tropical regions; 5. David (1987) — Phillipines; 6. Teh (2011) malaysia; 7. Dumas and Printemps (2010) New Caledonia/Dumas and Fossey (2009) Vanuatu; 8. Sujaul et al 2012 from Morgan 2005; 9. Rude et al 2015 — Indonesia

A2 Table 3: Final parameters used in runoff model

Landcover	C Factor
Bare soil	1.0
Larger urban centres	0.25
Cultivated land	0.2
Medium crowned second-growth forest (>50% disturbed)	0.09
Medium crowned second-growth forest (<50% disturbed)	0.006
Small crowned second-growth forest (>50% disturbed)	0.003
Small crowned second-growth forest (<50% disturbed)	0.003
Low montane primary forest	0.001
Open forest	0.009
Woodland	0.007
Swamp grassland	0.001
Swamp woodland	0.003
Grassland	0.01
Mangrove	0.001
Oil palm plantation - mature	0.2
Oil palm plantation - immature	0.3

Note: See A2 Table 2 for relevant parameter sources.

Outputs from runoff model

N-SPECT computes sediment yield per area in mt/year. To estimate sediment concentration in river networks and at river mouths, we used the flow volumes per river (L) modeled by N-SPECT to calculate concentration of total suspended sediment (TSS, mg/L).

Accpoll1 = Maximum accumulated total suspended sediments (kg)

Conc1 = Local pollutant concentration (mg/L) i.e. expected pollutant concentration value (in this case, sediment) if a sample were taken at a given cell location

Runoff1 = Runoff volume (L) in streams (just the water flow)

RUSLE1 = Output of RUSLE (erosion) = sediment yield - used to calculate accumulated pollution

APPENDIX 3: ENGAGEMENT

Workshop 1

Port Moresby, March 2016

Attendees: Vanessa Adams (UQ), Vagi Rei, Emily Fajardo, Elton Kaitokai, Madeline Lahari, Joseph Jure, Malcolm Keako, Bernard Suruman, Fabian Taimbari, Barnabas Wilmott, James Sabi

The plan workshops are detailed below. In the workshop we:

- Reviewed the previous terrestrial and marine PoWPA priorities, the Marxan results and inputs with participants;
- Provided recommendations for updated targets and approaches (e.g., planning units, connectivity);
- Reviewed existing outstanding data items for immediate assistance from CEPA in securing data licenses;
- Presented draft priorities based on different approaches to integrated marine and terrestrial Marxan analyses;
- Provide an opportunity for participants to nominate gaps in the data or priorities and to review spatial locations of priority sites.

Recommendations:

- Agreed upon planning units: Marine. Will maintain existing 'deep sea' priorities. Therefore for the revised analysis marine units will only be coastal shelf planning units. Terrestrial: will use subcatchments.
- Agreed upon targets: Maintain previous PoWPA targets. For vegetation targets use 10% (previous analyses explored 10% and 20%).
- Action items on missing data. Letters to be written
- requesting:
    - Mineral resources authority (Mining concessions)
    - Petroleum and gas exploration/mining concessions
    - Forestry Authority — FIMS 2009 data and current forestry concessions
    - 2011 Census Data
    - Special agriculture and business leases (SABL)
    - National Fisheries authority (Fisheries data, spawning aggregations, marine database)
    - NMSA - shipping data and other relevant data
    - National museum - registered sacred sites
    - Oil palm concessions/planned expansions
    - Urban areas/major towns
    - Bishop museum data (Emily to help contact Allen Allison)
- Agreed upon method for including data on costs/ constraints: Areas currently under use or under immediate development will be excluded from the analysis (pending data from relevant sources above). The tenements will be overlaid on new priorities so that users can identify potential future conflicts.

- Agreed upon approach for connectivity from workshop: run land-sea priorities together in order to prioritize connected ridge-to-reef units.
- Time line for remainder of project:
    - Establish a technical working group within CEPA to help drive day-today aspects of project
    - Acquire all relevant data urgently (no later than May)
    - Incorporate new data by June
    - Hold next workshop in June — 1 day just CEPA staff, 1 day possibly with external partners/ stakeholders (e.g. departments that have provided data). The key aim of the workshop will be to review the draft priorities and to identify any remain gaps in data or any issues with the priorities. The secondary aim will be to review draft planning products (e.g. maps at national and provincial level, tables of values within priority areas) and provide suggested amendments

- Half day training workshop in June — with key staff that are familiar with GIS and want to learn technical aspects of Marxan (to be held in CEPA office)
- Following the June workshop CEPA staff to circulate priorities with stakeholders and experts to receive external review and comment
- External comment to be provided back to UQ with any requested changes to analysis/ priorities by August
- Project ends in September with delivery of final priorities and all planning products (per June workshop guidance)

Workshop 2

Brisbane, August 2016

Attendees: Vanessa Adams, Viv Tulloch, Emily Fajardo, Patricia Kila, Kay Kalim, James Sabi, David Mitchell, Fiona Leverington, Nate Peterson, James Allan

The purpose of this workshop was to review draft final priorities, to discuss timing of small group training, review of priorities by experts and final delivery of the project in February 2017.

Agreed pathway for finalizing Land-Sea Assessment:

- Delivery of draft priorities and supporting planning documents to CEPA September
- CEPA review with experts and approve October – November
- Final planning products delivered February at workshop – proposed dates February 27-March 3

Workshop 3

Port Moresby, September 2016

Attendees: James Allan and Malcolm Keako

The purpose of this workshop was to hold a small group training session on Marxan and data delivery of data inputs in priority setting. In this workshop we met with key staff with capacity in ArcGIS and previous Marxan training. We delivered all data sets used and draft marxan runs. We reviewed how to open these data sets and Marxan runs with key staff.

Workshop 4

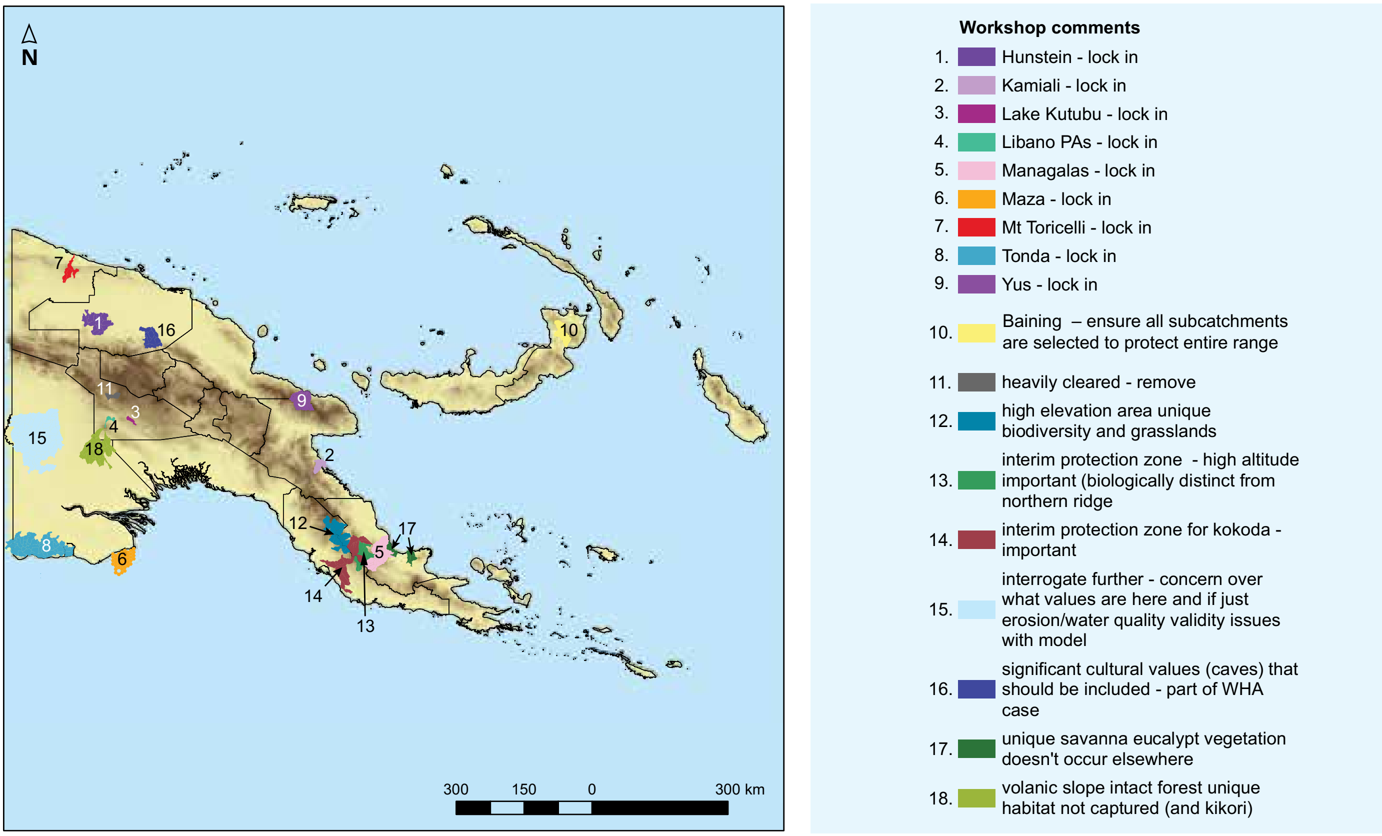
Brisbane, October 2016

Attendees: Vanessa Adams, James Allan, Nate Peterson, Fiona Leverington, Peter Hitchcock, Jehu Antiko, Alex Drew, Stephen Richards, Allen Allison, Kay Kalim, James Sabi, Alu Kaiye, Malcolm Keako, Patricia Kila, Mat Wolnicki, Andrew Krokenberg

The purpose of this workshop was to bring together relevant stakeholders and experts to review the conservation priorities and to identify any final gaps or modifications. Key changes to the analysis as agreed upon from the workshop are summarized below (see A3 Figure 1). Possible follow up workshop with additional experts identified for November. Similar approach will be taken and any other recommendations incorporated into analysis.

Recommendations:

- Lock in key protected areas (9 terrestrial, 1 marine)
- Three areas identified in separate assessment as interim protection zones in kokoda trail region locked in due to high biodiversity and unique features.
- Large area in central west region selected due to land-sea connectivity identified as an issue. This region is degraded due to upstream mining activities and does not have any special biodiversity features. Agreed to lock out. Further investigation to refine exact areas to lock out, such as zones around degraded streams, could target what subcatchments are best to lock out but in meantime it was agreed to lock out full region being selected as a priority due to connectivity.
- Heavily cleared area in highlands not captured by current vegetation mapping locked out.
- Four areas with unique features not captured with existing data sets and targets mapped and locked in.



A3 Figure 1: Key changes to the analysis as agreed upon from the workshop

Workshop 5

Port Moresby, November 2016 — National Expert Review Workshop

Expert Review Workshop Papua New Guinea (PNG) is one of the world's mega diverse regions, containing an estimated 7% of the world's biodiversity in less than 1% of the land area. The country as a whole combining Indonesia's West Papua region contains the largest contiguous area of forest remaining in the Asia-Pacific region and constitutes the third largesttropical rainforest in the world. PNG has more than 18,894 described plant species, 719 birds, 271 mammals, 227 reptiles, 266 amphibians and 341 freshwater fish species where endemism probably exceeds 30% for PNG and is well over 70% for Papuasia. It is also important to note that large gaps remain in the scientific knowledge of PNG's biodiversity, and new species are constantly being discovered. These facts render the need for CEPA to take lead via policies and regulations to protect State natural attributes as well as facilitate for meaningful benefits to community custodians.

The CEPA has established the PNG Protected Areas Policy (PA Policy) which reflects several pillars, one of which is to establish and manage protected areas. The five (5) pillars are:

1. Governance and Management
2. Sustainable livelihoods for communities
3. Effective and adaptive biodiversity management
4. Managing the PNG Protected Area Network
5. Sustainable and equitable financing for Protected Areas. CEPA consultations with resource agency sectors have resulted in the need to establish high priority conservation areas as conservation is considered as another landuse. PNG currently has Programmes of Work for Protected Areas (PoWPAs) for the terrestrial and marine environments completed at different times which identify conservation priorities. There was need to integrate such previous work and hence the objective of the current PoWPA Project.

The CEPA, in partnership with UNDP, is implementing a GEF-funded project on Community-based Forest and Coastal Conservation and Resource Management in the Papua New Guinea (CbFCCRM). The CbFCCRM Program is assisting CEPA with the Programme of Work Protected Areas (PoWPA) through the engagement of University of Queensland to assist to incorporate marine and terrestrial protected areas in order to highlight biodiversity hotspots so as to guide other resource developments as well as facilitate for meaningful conservation actions. In addition, it is important for CEPA to declare protected areas over sensitive areas that are of national interest as well as global interest.

The objectives of the review workshop of the PoWPA Project as part of priority setting for biodiversity conservation (including Marxan analysis) was for the University of Queensland/TNC Project Consultants, to present draft priorities based on integrated marine and terrestrial Marxan analyses. The workshop provided an opportunity for stakeholders and government agencies in PNG to nominate gaps in the data or priorities and to allow for review of spatial locations of priority sites. The expected outcome of the workshop was to map with details draft PNG priority Biodiversity Conservation areas.

Day 1: 24 November 2016

Presentation 1: PNG PoWPA: Terrestrial Analysis (2008–2010) — Nate Peterson (TNC)

Notes from presentation:

- A goal of sustainability is to find the balance between Development and Protection.
- Spatial priority analyses such as those under PoWPA in PNG help to
  • assess effectiveness — protecting current PA system
  • I dentification of potential protected/ conservation/ managed areas
- Marxan Prioritization Tool used:
- Marxan identifies the geographical systems, land systems, vegetation, endemics (endangered species) of a particular area.
- There must be a plan for the Implementation process
- Way forward:
  - Build off prior conservation priority research, recognizing that a short list of priority areas come up in every analysis.
  - Sub-catchments provide a useful geographic feature for considering potential conservation areas. – Include land-sea connectivity

Comments/questions

1. **Eco regions broad may not work** - could use geological makeup of PNG to decide priority area for conservation.
2. **Rare and restricted species** - seems like current PoWPA focus on mammals and reptiles only - other species such as insects, plants and insect plants how they are going to be included in this PoWPA.
3. **How much is enough** - 10% CBD protection target - landmass 1% and biodiversity 7%.

Presentation 2: Review and integration of the Terrestrial and Marine PoWPA — Nate Peterson (TNC PNG PoWPA: Terrestrial Analysis (2008–2010), Nate Peterson (TNC)

Notes from presentation:

- Sustainability provides the balance between the Development and Protection.
- PoWPA Workshop is vital because:
  • Assess of effectiveness- protecting current PA system
  • I dentify of Potential PA especially in PNG
- Prioritization Tool used:
  • Marxan
  • Marxan identifies the; geographical systems, land systems, vegetation, endemics (endangered species) of a particular area.
- There must be a plan for the Implementation process
  • Review and Integration of the Terrestrial PA systems
  • Work on National Scale Planning
  • Existing priorities: Marine PoWPA
  • Areas with Fishing Pressures
- Way forward:
  • Build existing PoWPAs
  • Revise terrestrial planning using sub- catchments
  • Include land-sea connectivity

Comments/questions

1. To have intensive profile for priority areas so we know what prompted conservation priority
2. Climate refugia — some features of climate refugia are not arising in the marine selections, needed to capture.
3. Climate change refugia for Terrestrial biodiversity - what was the kind of connectivity - the connectivity for terrestrial climate change is altitudinal range.
4. Hexagon planning units - what sort of criteria use? The response was that within a planning unit what is inside it - priority such as 10% mangroves, 50 rare species, etc.

Presentation 3: Protected Area Planning for the Kikori River Basin - Nathan Whitmore & Jane Mogina

A presentation was made by Wildlife Conservation Society (WCS) presentation as part of Exxon Mobil offset initiative on a case study of the PoWPA work done in PNG using Marxan software.

The project boundary was recommended by WWF and WCS added a buffer around it. When the project ends, the outputs including data will be submitted to CEPA to be taken on board as a pilot PA in PNG.

Comments/questions

1. What level of confidence to have in the final products- key things
2. Social and cultural - where to prioritize and plan - community and cultures define important value - sustainable use of cultural important species.
3. Prioritize Slope between 10–45, any reason? Restrict movement upwards

Review of Integrated Priority Analysis: Led by Nate Peterson (TNC), representing the analysis led by Vanessa Adams and Viv Tulloch (University of Queensland)

Nate reviewed the analysis of the Integrated Terrestrial and Marine with inputs from the participants. (Refer to Area review notes - Tables A3 1-4)

GIS maps were projected to the screen so that participants could systematically work through all regions of PNG. Within each region, or Province, participants considered their expert knowledge in relation to the 'Best Solution' features identified in the UQ analysis. Additional reference data was provided to orient participants and also to flag existing protected areas (also known as a managed areas) and proposed World Heritage Areas. The combination of existing/proposed sites, the UQ priority areas, and expert knowledge in the room yielded 81 unique areas that should be considered for priority action. Notes were captured during the interactive session and recorded in this GIS dataset. Additional notes were recorded below and by CEPA staff. The GIS data for these 'Areas of Interest' are represented in the feature class called: 'Priority_Areas_of_Interest' (see A3 Figure 2 on page 60)

Within these AOI's we then selected out the planning units from the UQ analysis that have a 'Best Solution' value of '1'. These GIS data are represented in the feature class called: 'Priority_AOI_Best' (see A3 Figure 3 on page 60)

An ArcGIS Personal Database with the two feature classes noted and illustrated above has been sent to CEPA staff.

Staff at CEPA that will be taking these areas on board for priority action will need to further investigate associated notes so that the larger list of 81 Priority Areas of Interest can be filtered down to a shorter list. From there the UQ team could then work to develop profile fact sheets to help raise awareness of these areas. This information will assist CEPA in their negotiations with stakeholders across all scales.

A3 Table 1: Area review notes for Momase Region

Sandaun	East Sepik	Madang	Morobe
• Torrecelli Range - existing site • Hindenberg Wall - biodiversity, Karst, cultural, spp significance • Hunstein Range - existing site • Scotchio - Karst system, pine trees	• Mount Puru • Karawri Place- Caves • Proposed site (Mt Turu)south of Torecelli site, on north side of Sepik River. Proposed by MP • Vokeo Island group - set up LMMA • Vokeo Island group - set up LMMA	• Turkey-Bird watching • Area around Ramu Nickel Mine • Interesting that Wanang does not show up in analysis • Wanang has long term research site (50 ha) • Area around Ramu Nickel Mine has potential • R2R stretch down to Karkum has potential. Connects to bird areas in hills and existing sites on coast. Could link across to Karkar island • Long Island — boundary for WMA needs review • Whale migratory path near Karkar Island • Madang Lagoon — fishing for livelihood • Vitaz Strait — turtle nesting	• YUS - locked in • Area around Huon Steps & Nusareng WMA - Cromwell Range • Buang - cultural, sacred site • N Huon Coast - turtle nesting beaches • Vitiaz Strait - Whale migratory pathway • Cromwell Range • Lake Trist - Note that it should focus on patch from UQ • Mt Strong - suggested by JS

Source: List developed during workshop

A3 Table 2: Area review notes for Southern Region

Northern	Central	Milne Bay	Gulf	Western
• Kokoda Track - • existing, in process • Managalas proposed CA/ existing - in process • Musa Plains - Savanah, as noted at UQ meeting • Mt Suckling - Unique structure of mountains	• North Owen Stanley - as noted at UQ meeting. Mt Albert Edward, Mt Victoria • Varirata NP and catchments to the east. Discussion to extend SW down to Bootless Bay - Ties in with Pacific Adventist University • Mt Victoria • Mt Albert Edward • Boothless Bay Area - proposed MPA • Mt Yule • Kosipe WHA • Mt Brown • Mt Kenevi • Orangerie Bay - prawn • Table Bay - leatherback/dolphins • Galley Reach Mangroves, igratory birds • Table Bay - Leatherback nesting and dolphins	• Mt Thompson • Rossel Island • D'Entracasto Islands - high endemism, never connected to mainland, high islands • Woodlark Island • Mt Victory • Mt Damen (endemic frogs) • Mt Simpson (endemic frogs) • Milne Bay islands - Areas noted. • Vakuta - turtle migratory path, rest stop for green and hawksbill turtle • Pocklington Reef - off shore reef with lowpressure • Eastern Fields - whale zone • Mt Simpson and Damen East Cape - Hammered a bit from population • Yela Island - Unique land and reef types • Vakuta - turtle migratory path, rest stop for green and hawksbill turtle • Pocklington Reef - off shore reef with low pressure • Eastern Fields - whale zone • Mt Simpson and Damen • East Cape - Hammered a bit from population • Yela Island - Unique land and reef types	• Dalai Mountains • Goaribari Island - Freshwater dolphin, fresh water turtle nesting. Research from UPNG, Canberra Univ.	• Tonda - good to keep

Eastern Fields — Whale zone, Pressure from Asian fishing — South of Central and Milne Bay
Source: List developed during workshop

A3 Table 3: Area review notes for Highlands Region

Southern Highlands	Eastern Highlands	Western Highlands	Simbu
• Mt Sisa - Tari, 3000m plus • Mt Murray - Archaeological site • Mt Murray / Mt Giluwe - arch site, biodiversity value • Mt Bosavi	• Mt Gahavisuka - good to keep • Crater Mountain - Good to keep • Mt Michael - Proposed CCA	• Kuk WHS	• Mt Wilhelm - Binatang has transects up the slope, connects to Wanang • Mt Eliambari • Karamui

Source: List developed during workshop

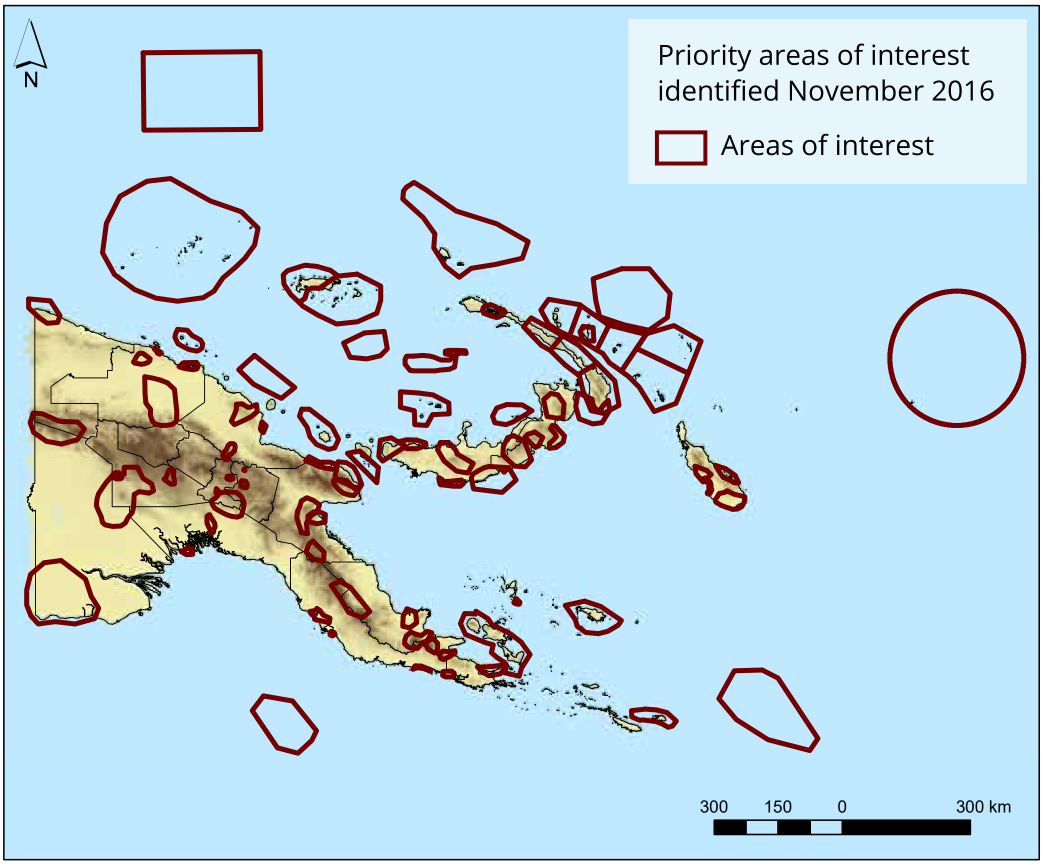
A3 Table 4: Area review notes for Islands Region

Bougainville	New Ireland	Manus	West New Britain
• Torokina Caves • Coral uplift • Pirung WMA (Eight Islands) - Good to keep • Near Jaba River - leatherback, green turtle, crocodile • Mt Balpi catchment area	• Group of Island @ Musau - extensive research, rare, threatened species • St. Martius Group of Island Reproduction area for the Tuna yellow fins. • Lihir • St Georges Channel - whale passage, turtle beach on point, communities on two larger islands • NI east islands — Each island likely has endemics • NI east islands — Each island likely has endemics • NI east islands — Each island likely has endemics • NI east islands — Each island likely has endemics • NI east islands — Each island likely has endemics • Mussau Group of Isalnds - Extensive research, SDA community, rare and threatened species	• Whole Island • Group of Islands • Circular Reef - Titan tribes working here	• Kandrian Coast - Good fishing grounds, set up LMMA • Bali Witu Islands - Deep water habitats, whale, dolphins • Bismarck Sea - proposed whale sanctuary

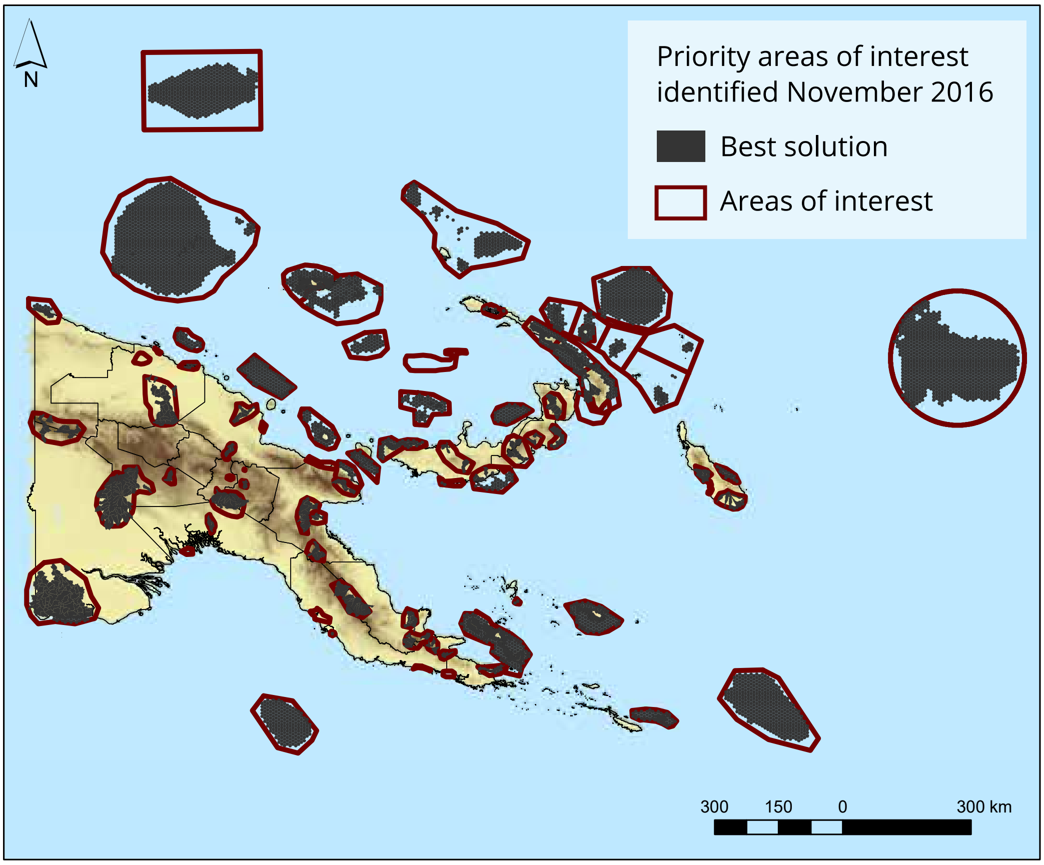
Murdogado Square — Tuna breeding grounds — North above Manus & New Ireland

Source: List developed during workshop

Spinner dolphins and volcanoes in New Ireland Province are just some of the beautiful attractions on offer in PNG © Alice Plate/ UNDP



A3 Figure 2: Priority areas of interest



A3 Figure 3: Priority areas of interest - best

Day 2: 25 November 2016

Review of analysis — continued from Day 1

Nate reviewed the analysis of the Integrated Terrestrial and Marine with inputs from the participants (refer to Area review notes Tables A3 1–4).

Data gaps identified

This section provides brief notes on data gaps that were identified and in some cased directly addressed by sharing data from other government offices.

1. MRA Mining Leases
   - Data shared to CEPA / TNC
   - Current to Oct 2016
2. MRA Exploration Leases
   - Data shared to CEPA / TNC
   - Current to Oct 2016
3. MRA Special Mining Leases
   - Data shared to CEPA / TNC
   - Current to Oct 2016
4. Forest Concessions
   - Data shared to CEPA / TNC
   - Current to 2013
   - Area logging
5. Cleared forest areas
   - FCAS in combination with SGS Log Export Data to determine extent of trees cleared in a given area.
6. SABL areas
   - ANU has worked to demark these boundaries
7. Bird species
   - Limited use of birds in UQ analysis, only Birds of Paradise used
   - Used IUCN species list
8. Mammals
   - Check if they used Tree Kangaroos
9. Cultural sites
   - Data difficult to obtain
   - National Museum may have some info.
10. Oil Palm sites
    - TNC has Oil Palm for Kimbe Bay (NBPOL) and Tzen Niugini in East Pomio
    - Should get Oil Palm New Ireland, Ramu Valley, Milne Bay, Northern Province

Oil Palm, Kimbe, PNG © Nate Peterson/ The Nature Conservancy

A3 Table 5: List of participants

Day 1: Thursday 24 Nov 2016						
No.	**Name**	**Organization**	**Designation**	**Phone**	**Email**	**Signature**
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12	Vagi Rei	CEPA				✗
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Day 2: Friday, 25 Nov 2016						
No.	**Name**	**Organization**	**Designation**	**Phone**	**Email**	**Signature**
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3	Ted Mamu	JICA/CEPA	Technical Coordinator	72159893	chrysencious@gmail.com	✔
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5	James Sabi	CEPA	Manager TEM	3014520	jsabi@dec.gov.pg	✔
6	Benside Thomas	CEPA				✔
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14	Emily Fajardo	UNDP				✕
15	Constin Bigol	PNGFA	Forester	70087584	cbigol@pngfa.gov	✔
16	Nick Araho	NMAG				✕
17	Simon Saulei	UPNG				✕
18	Nate Peterson	TNC	GIS Manager	71634193	npeterson@tn.org	✔
19	Ruth Konia	TNC				✔
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25	Ian Woxvold	IWC				✕
26	Stephen Richards	SJR				✕
27	David Mitchell	ECA	Director	72003300	dmitchell.eca@gmail.com	✔
28	Magaru Riva	ExxonMobil	Snr Advisor	70318542	magaru.riva@exxonmobil.com	✔
29	Tau Morove	ExxonMobil	Snr Advisor	70682680	tau.morove@exxonmobil.com	✔
30	Daniella Turu	CEPA	Intern	75822913	dturusamngar@gmail.com	✔
31	Babara Masike	TNC	Program Director	71704465	bmasike@tnc.org	✕
32	Jennifer Gabriel	James Cook University		0437 761 512		✔
33	Colin Filer	Australian National University				✔

Workshop 6

Port Moresby, March 15–16 2017

Prof Hugh Possingham, Nate Peterson, James Allan and Caitlin Kuempel delivered the final priorities and associated report to CEPA. During this workshop the team discussed with CEPA implementation strategies and how to further refine the 81 Areas of Interest.

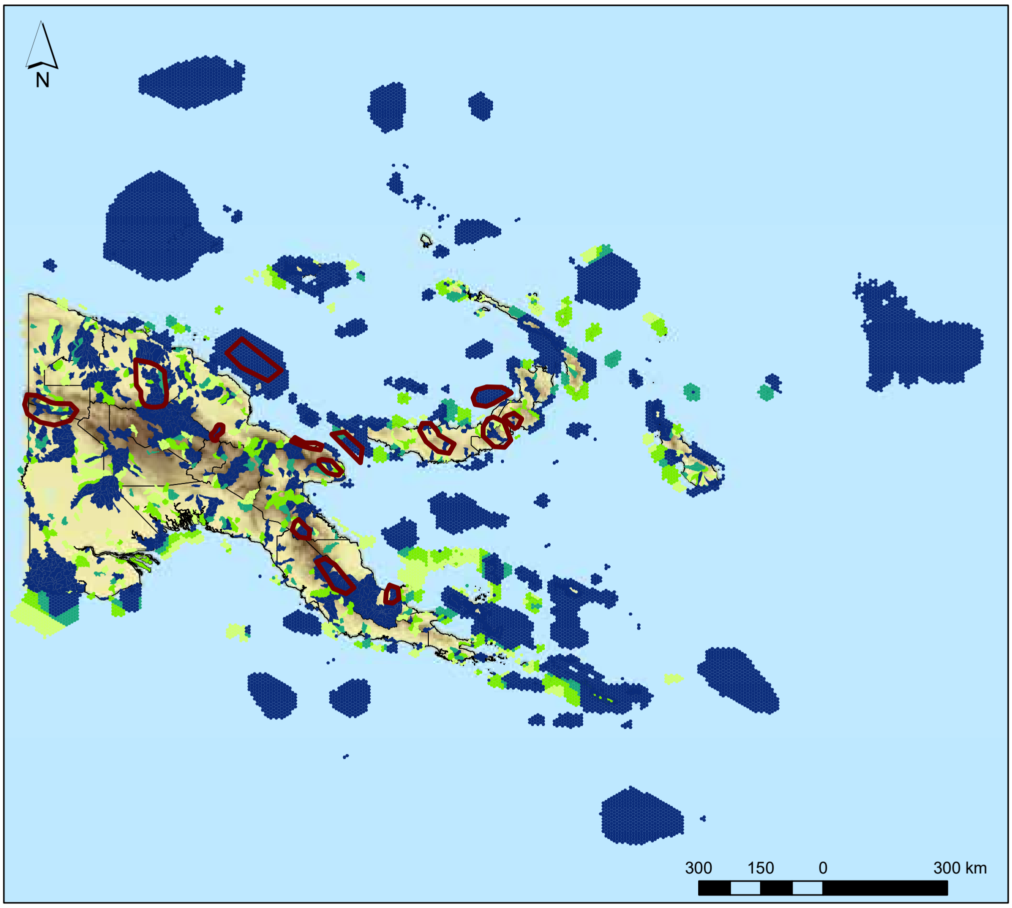
Land-sea conservation assessment for Papua New Guinea: Final deliverable meeting Hosted by UQ team at Lamana Hotel, Port Moresby

March 15-16, 2017

PNG is committed to the establishment of a network of protected areas to fulfil national and international commitments. The primary objective of the National Scale Conservation priority Assessment was to provide an updated set of conservation priorities by integrating Terrestrial and Marine PoWPA in PNG; this set of conservation priorities can be used as a roadmap for meeting conservation targets that fulfill PNG's global conservation commitments (e.g. under the CBD Aichi 11 targets) as well as national targets (such as the Protected Areas Policy). The project team and collaborators met with CEPA staff to provide the final report and discuss the outcomes of the assessment and production of final planning products. The final report and national scale map of priorities will be delivered to CEPA as key implementation products for national scale conservation initiatives.

In previous workshops, CEPA and biodiversity experts identified 81 Areas of Interest. These are areas that are priorities for immediate action due to aspects such as overlapping priorities with other policies and priorities, such as proposed World Heritage Areas, or areas under immediate threat. During this workshop, of these 81 areas, a short list of areas was identified for production of factsheets. The short list was divided into an 'A' list of national scale immediate priorities and an 'A1' list of provincial scale immediate priorities (see A3 Figure 4 & A3 Figure 5). The A and A1 lists focus on the 8 provinces which are the focus of GEF 5 and 6 (E Sepik, W Sepik (Sundown), Madang, Morobe, Central, Oro, E New Britain, W New Britain) because there are funds/support for action in these places. However, CEPA will continue to build these lists for the remaining provinces. The Areas of Interest A and A1 lists are areas considered critical for short term action due to the presence of significant endemic species, political opportunity for action (such as existing protected areas), community support or existing NGO initiatives to support action, and ecosystem services for people. It was noted that these lists should be used to guide immediate action, but that opportunities across all priority areas should be kept in mind. Meeting PNG's conservation targets requires activity across all priority areas, not only within Areas of Interest. To support action within these Areas of Interest, the UQ team and collaborators are creating factsheets that highlight the values present in these areas, such as endemic species or existing conservation initiatives. These factsheets will provide support to CEPA and collaborators when scoping local implementation of conservation actions.

Workshop, PNG © James Allan/ University of Queensland

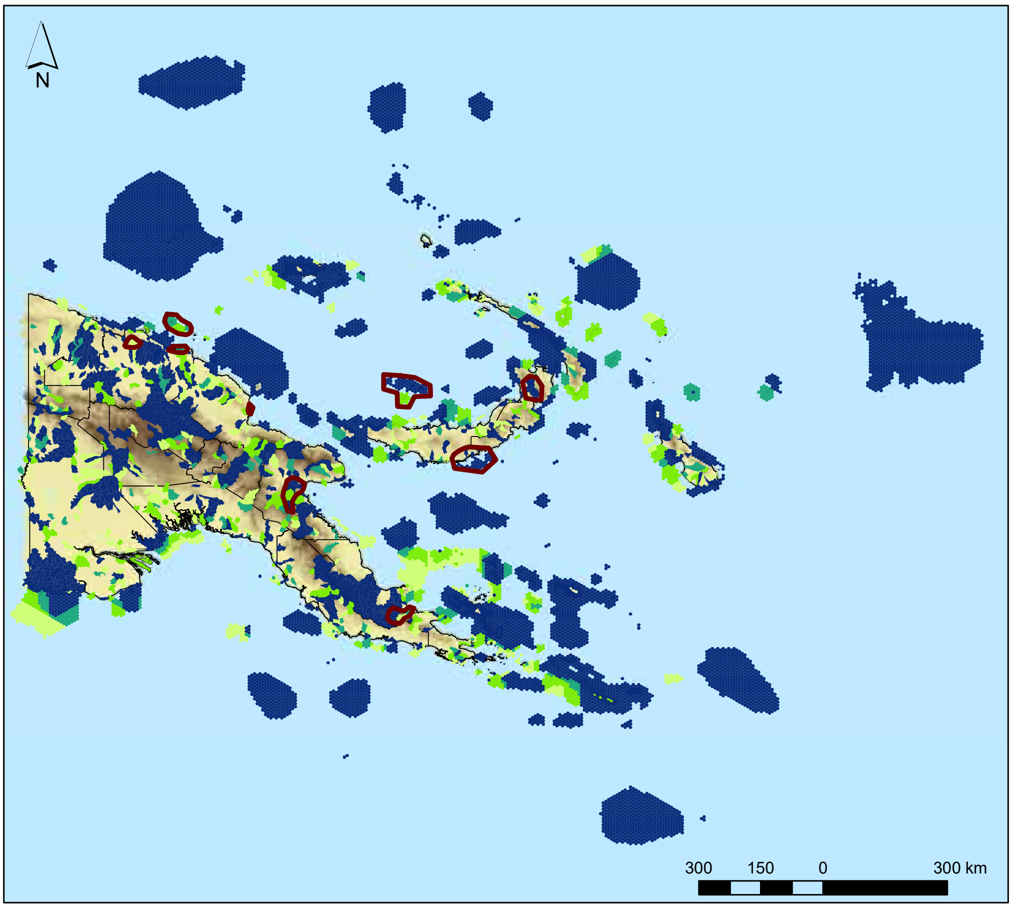


Land-sea conservation assessment priorities

Selection frequency

- 0 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- Areas of interest

A3 Figure 4: Conservation assessment priorities (selection frequency) and Areas of Interest for National concerns (List A)



Land-sea conservation assessment priorities

Selection frequency

- 0 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- Areas of interest

A3 Figure 5: Conservation assessment priorities (selection frequency) and Areas of Interest for Provincial concerns (List A1)

APPENDIX 4: CONSERVATION PLANNING SCENARIOS

A4 Table 1: Description of planning scenarios

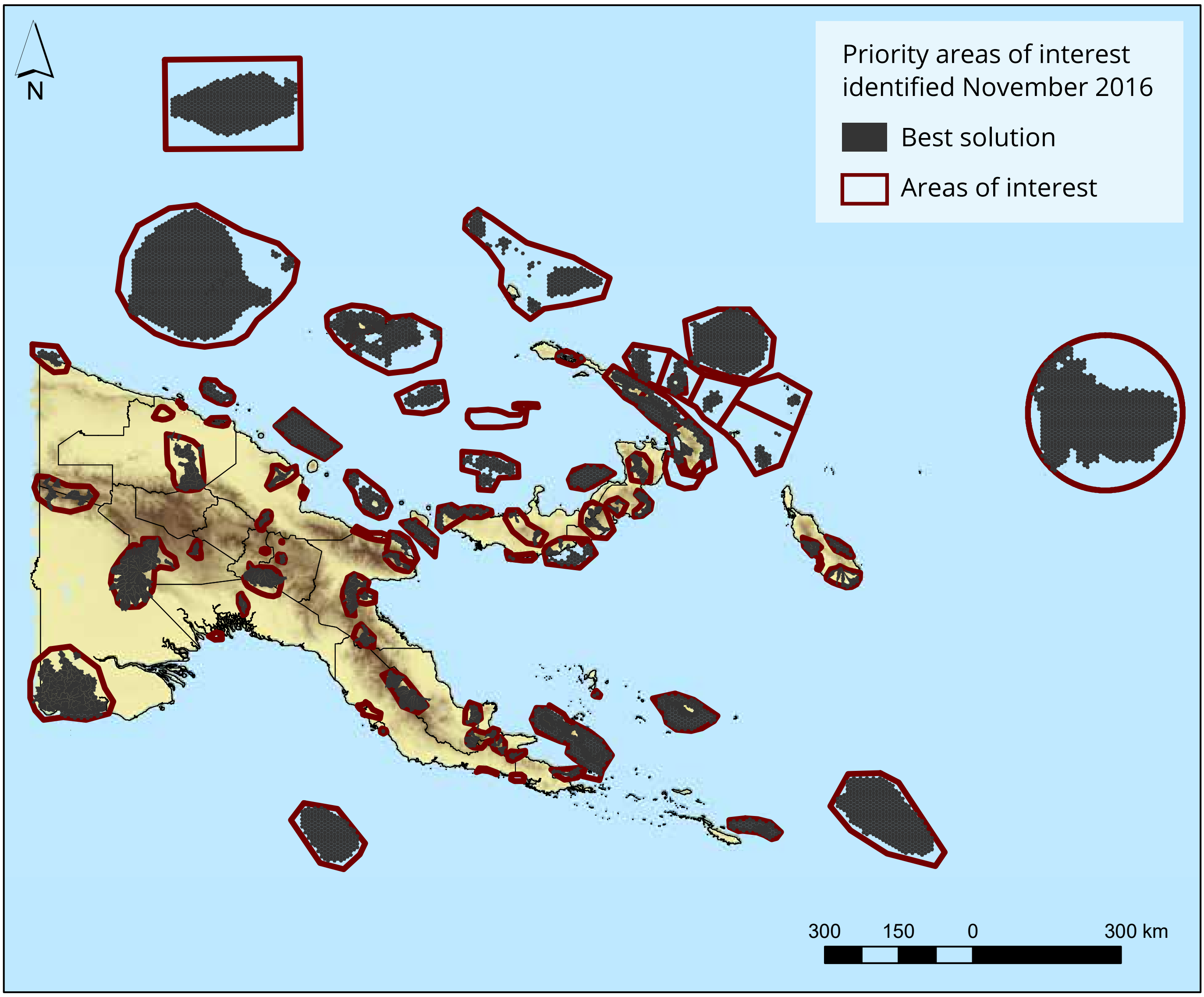
Scenario	Details	Land	Marine	Connectivity matrix considered	Approach
Standard land	Only land features considered	×		No	Standard (traditional clumping using BLM)
Land runoff	Only land features considered	×		Yes	Land-sea asymmetric connectivity
Standard marine	All marine features on the shelf available for selection, deep sea priorities locked in		×	No	Standard (traditional clumping using BLM)
Marine runoff	All marine features on the shelf available for selection, deep sea priorities locked in, plumes locked out		×	Yes	Standard (traditional clumping using BLM)
Standard land-sea	Land and marine features included	×	×	No	Standard (traditional clumping using BLM)
Land-sea connectivity - extreme avoidance	Land and coastal marine features considered, deep sea priorities locked in, removed land/sea pu overlap	×	×	Yes	Land-sea asymmetric connectivity
Land-sea connectivity - accept risk (FINAL SCENARIO)	Land and coastal marine features considered, deep sea priorities locked in, removed land/sea pu overlap, lower sediment threshold	×	×	Yes	Land-sea asymmetric connectivity

APPENDIX 5: FACTSHEET EXAMPLES FOR NEW BRITAIN

To be piloted and refined in collaboration with partner projects such as local mapping and planning project led by Nate Peterson, TNC

There are many ways to identify priority areas for immediate action such as further assessment and implementation of conservation management. The workshop held in Port Moresby November 24–25 identified 81 areas of interest based upon expert input (see A5 Figure 1). These were then intersected with the systematic conservation planning priorities identified by the Marxan land-sea analysis. This resulted in areas for further discussion and investigation by CEPA in order to refine to a final set of top priorities for implementation. This type of map should be used in conjunction with the full assessment map to ensure that other smaller priority areas are not neglected if opportunities arise for management within these regions.

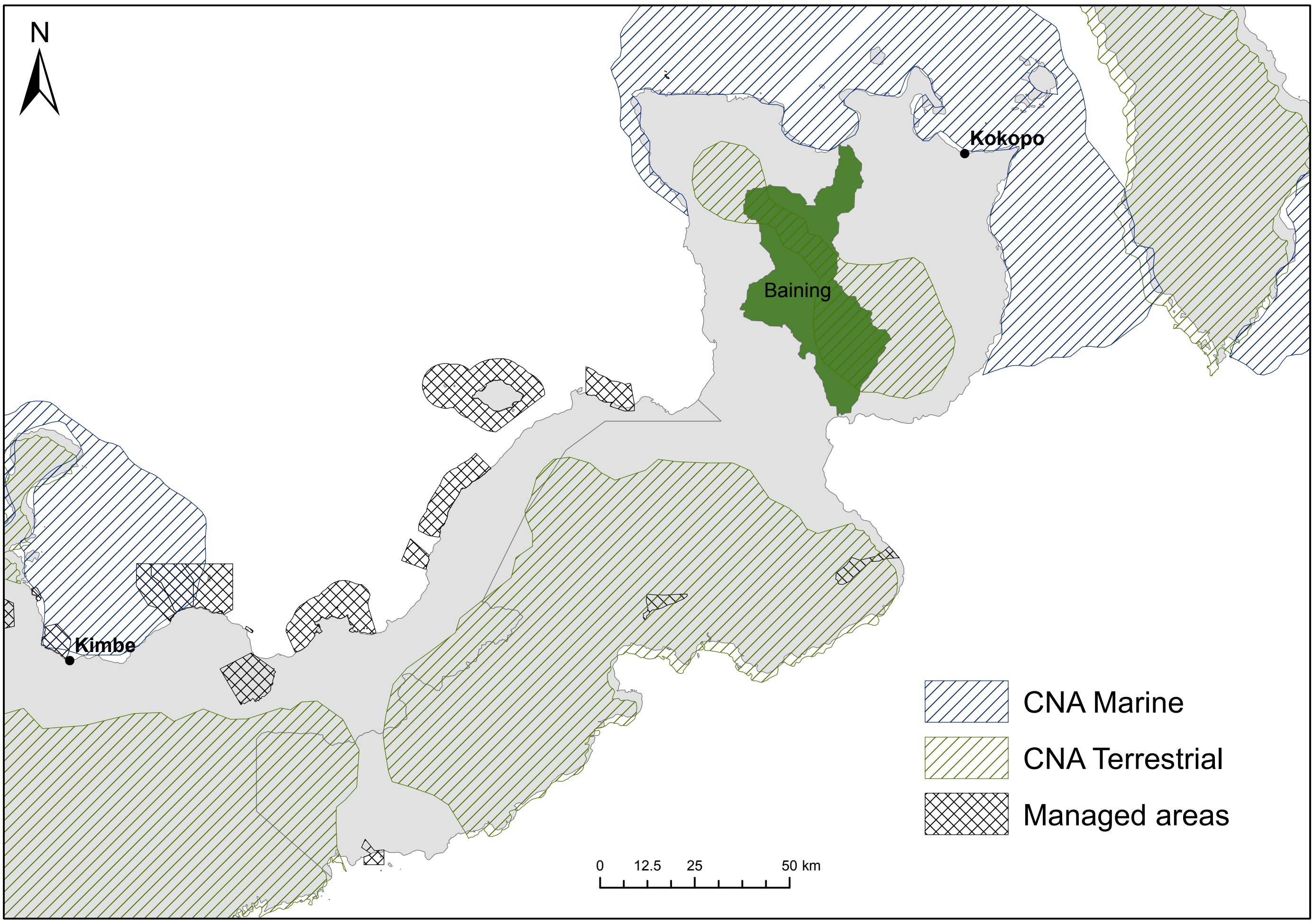
We present sample fact sheets for areas of interest in New Britain. These factsheets can be piloted in conjunction with existing work being undertaken in the region, such as world heritage assessments, management assessments and further land use planning.



A5 Figure 1: Priority Areas of Interest intersected with the spatial priorities from the Marxan land-sea analysis

APPENDIX 5. *CONTINUED*

Priority Areas of Interest in Baining, East New Britain.



BAINING

Province: East New Britain

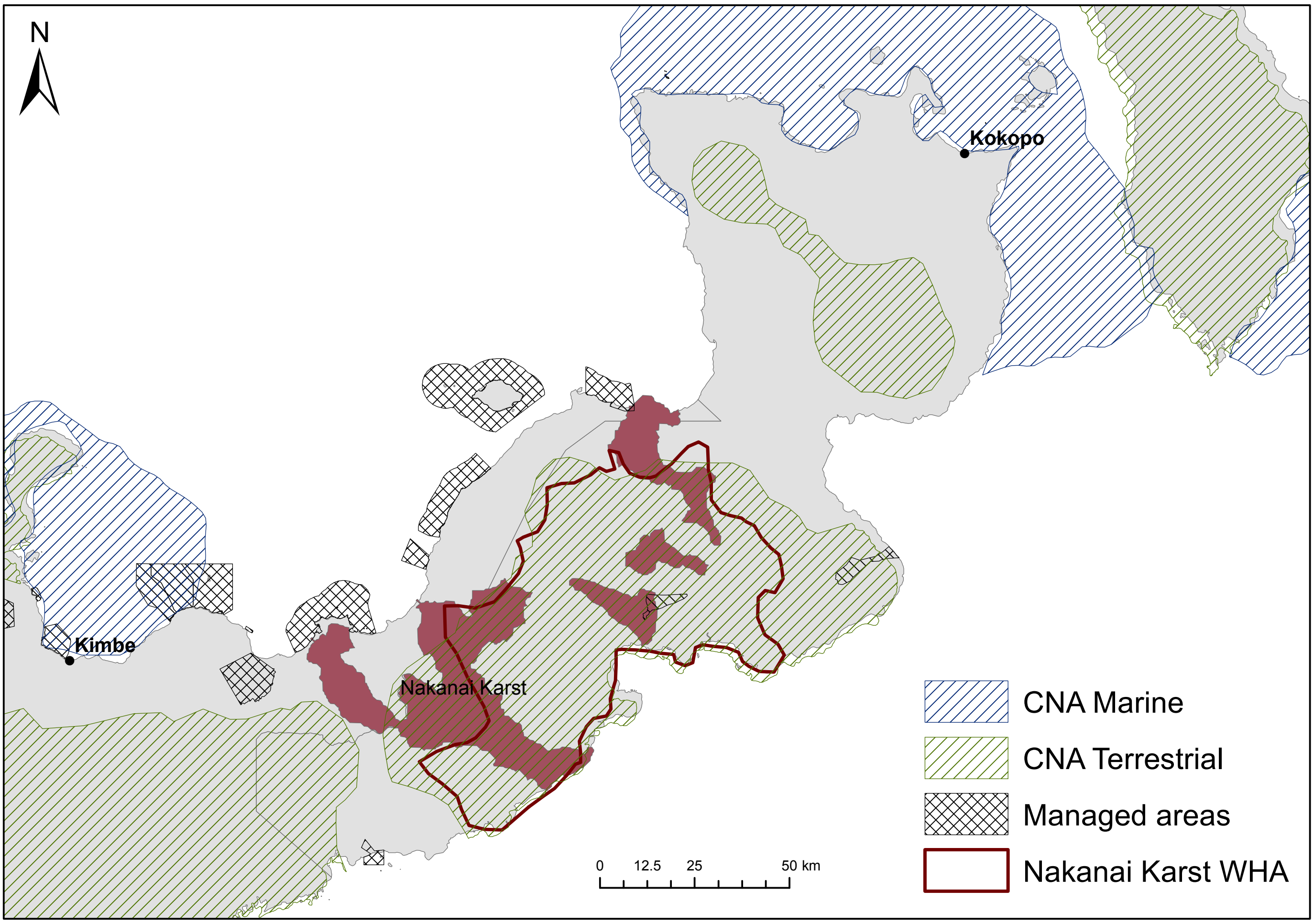
Total Area: 1,300 km²

This priority area is associated with the Baining Mountains. The mountain vegetation is primarily intact forest (<1% cleared); however the mountains are surrounded by lowlands with a growing populace.

Other assessment priorities and existing management arrangements: This region was identified in the Conservation Needs Assessment (CNA) as a terrestrial priority (T36 The Baining Mountains). There are no existing managed areas.

Aerial View Of Southern Baining Mountains, East New Britain © Nate Peterson/ The Nature Conservancy

Priority Areas of Interest in Nakanai Karst Region, East & West New Britain.



NAKANAI KARST REGION

Province: East and West New Britain

Total Area: 2,100 km2

This area is characterised by Karst limestone features and has four priority regions identified within it. It is ~2% cleared (predominantly for oil palm) and is dominated by a complex of forest vegetation (~90%) including lowland rain forest and montane forest, and forest dominated by Lithocarpus and Nothofagus developed on the limestone substrate. The Nakanai Mountains comprise a large uplifted plateau (mostly >1,000m) and constitutes the largest continuous expanse of montane forest in New Britain.

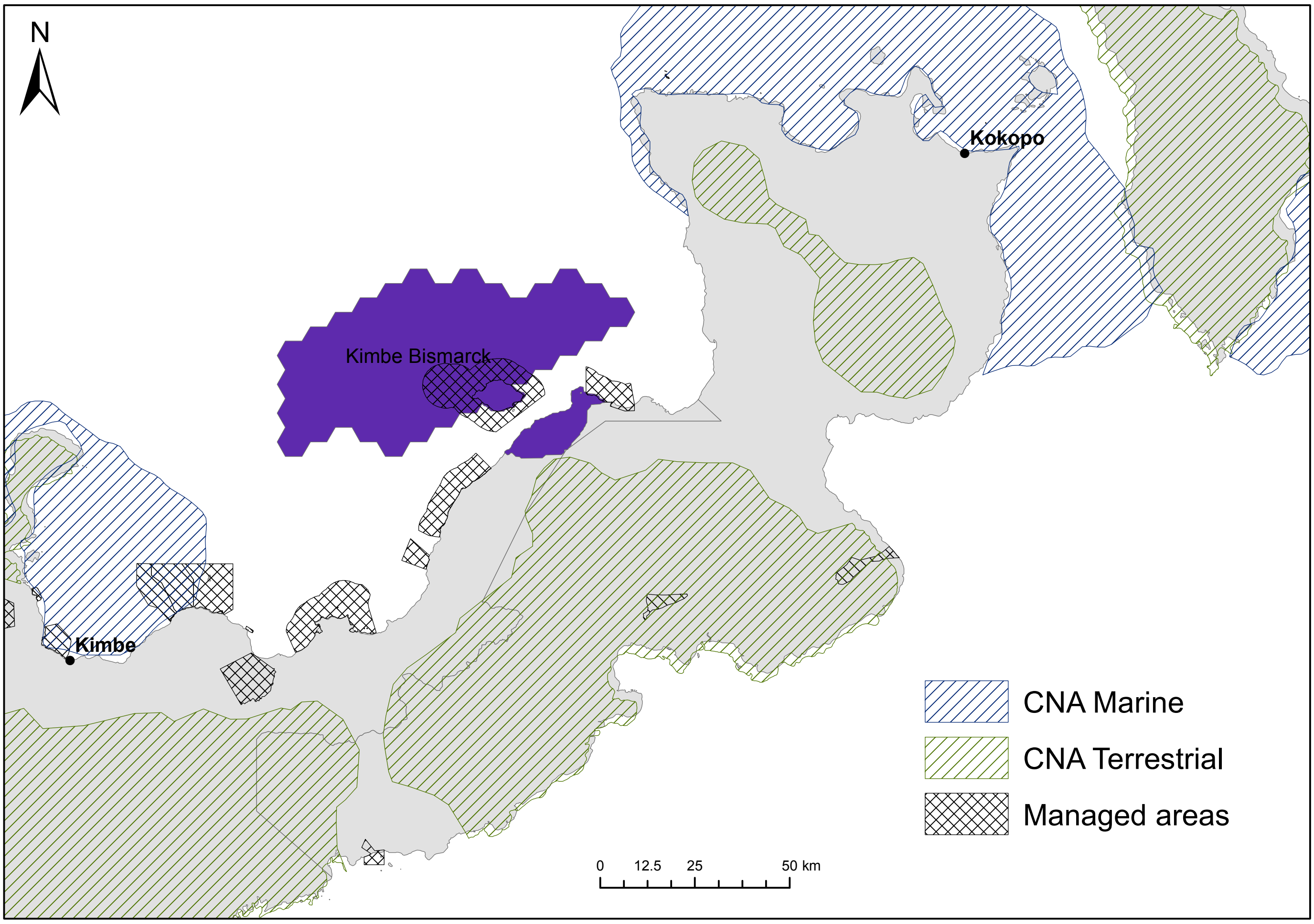
Other assessment priorities and existing management arrangements: This region was identified in the Conservation Needs Assessment (CNA) as a terrestrial priority (T13 Central and East New Britain) and is a proposed world heritage area (Nakanai Karst). There are two existing managed areas within this region: Klampun and Kavakuna Caves.

Range restricted/rare endemics:

- Platymantis nakanaiorum
- Platymantis sulcatus
- Platymantis mamusiorum
- Platymantis bufonulus
- Platymantis caesiops

Nakanai Plateau, New Britain, PNG © Stephen Alverez

Priority Areas of Interest in Kimbe Bismarck, West New Britain.



KIMBE BISMARCK

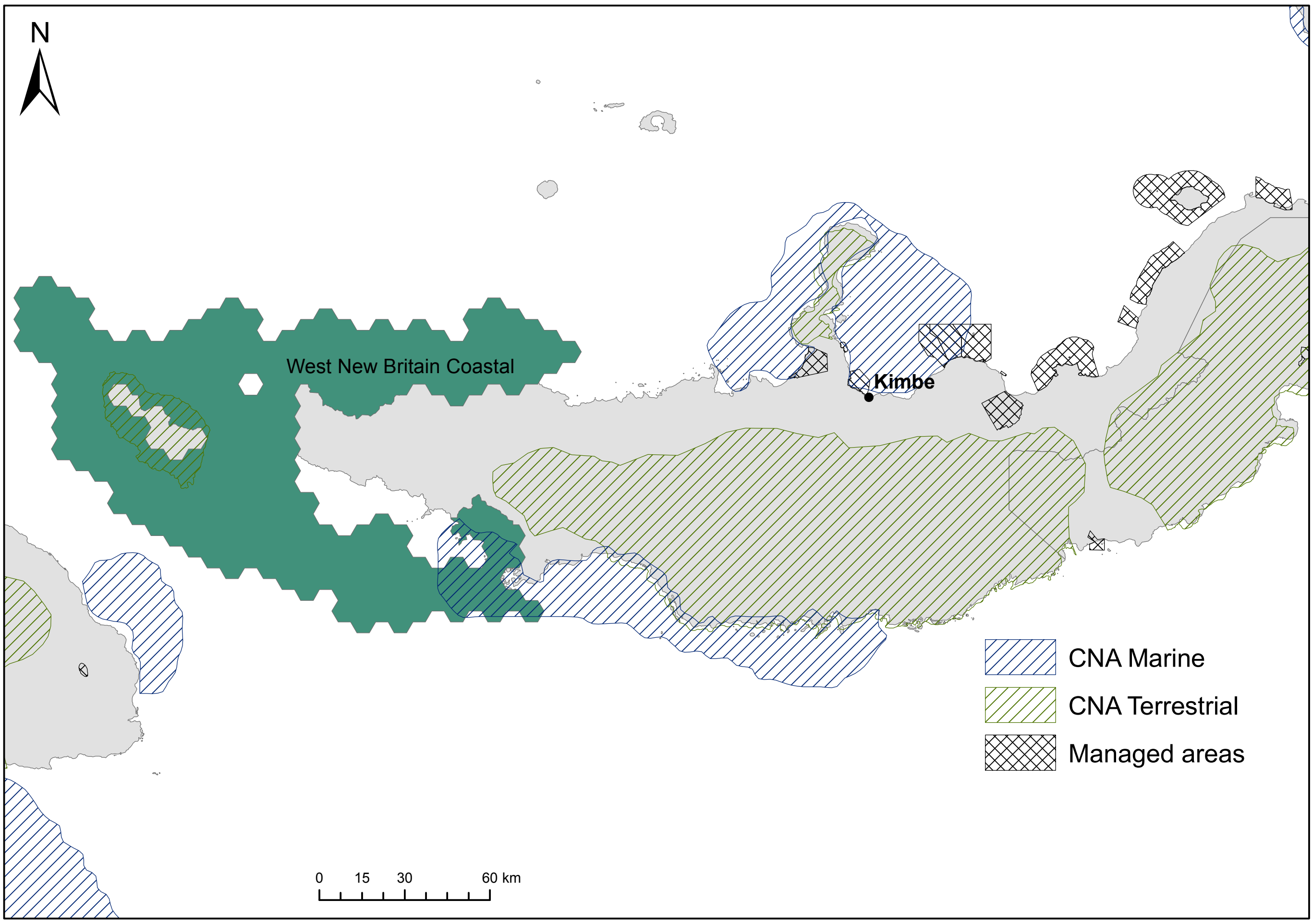
Province: West New Britain

Total Area: 3,000 km²

This priority area contains both terrestrial and marine ecosystems. The coastal area is 4% cleared, primarily for oil palm, and remaining vegetation is a complex of forests and volcanic successions.

Other assessment priorities and existing management arrangements: This priority region is within the Kimbe LMMA and there are two existing managed areas: Lolobau (marine) and Cape Torkoro (terrestrial).

Dolphins Jumping, Kimbe Bay, PNG © Vanessa Adams/ University of Queensland



Priority Areas of Interest in West New Britain Coastal Region, West New Britain.

WEST NEW BRITAIN COASTAL REGION

Province: West New Britain

Total Area: 11,400 km2

This priority area contains both terrestrial and marine ecosystems. The coastal area is largely intact (<1% cleared) and is primarily forests and coastal vegetation such as mangroves and swamps. Umboi Island is a major terrestrial priority feature. Umboi is the largest and richest of PNG's north coastal islands. It is home to populations of large numbers of species endemic to PNG, as well as a remarkable array of fruit bats (eight species). Lake Buan, in Umboi's highlands, supports one of the richest waterbird populations in the Bismarck Archipelago. The marine area contains raised limestone islands, mangrove and associated nursery areas, and seagrass beds. It contains the Vitiaz Strait which is a whale migratory pathway.

Other assessment priorities and existing management arrangements: This region has been identified as a priority in the Conservation Needs Assessment (CNA) as a terrestrial priority (T32 Umboi Island) and marine priority (M11 Fullberborne). There are no existing managed areas.

Threatened species:

- Dendrolagus matschiei

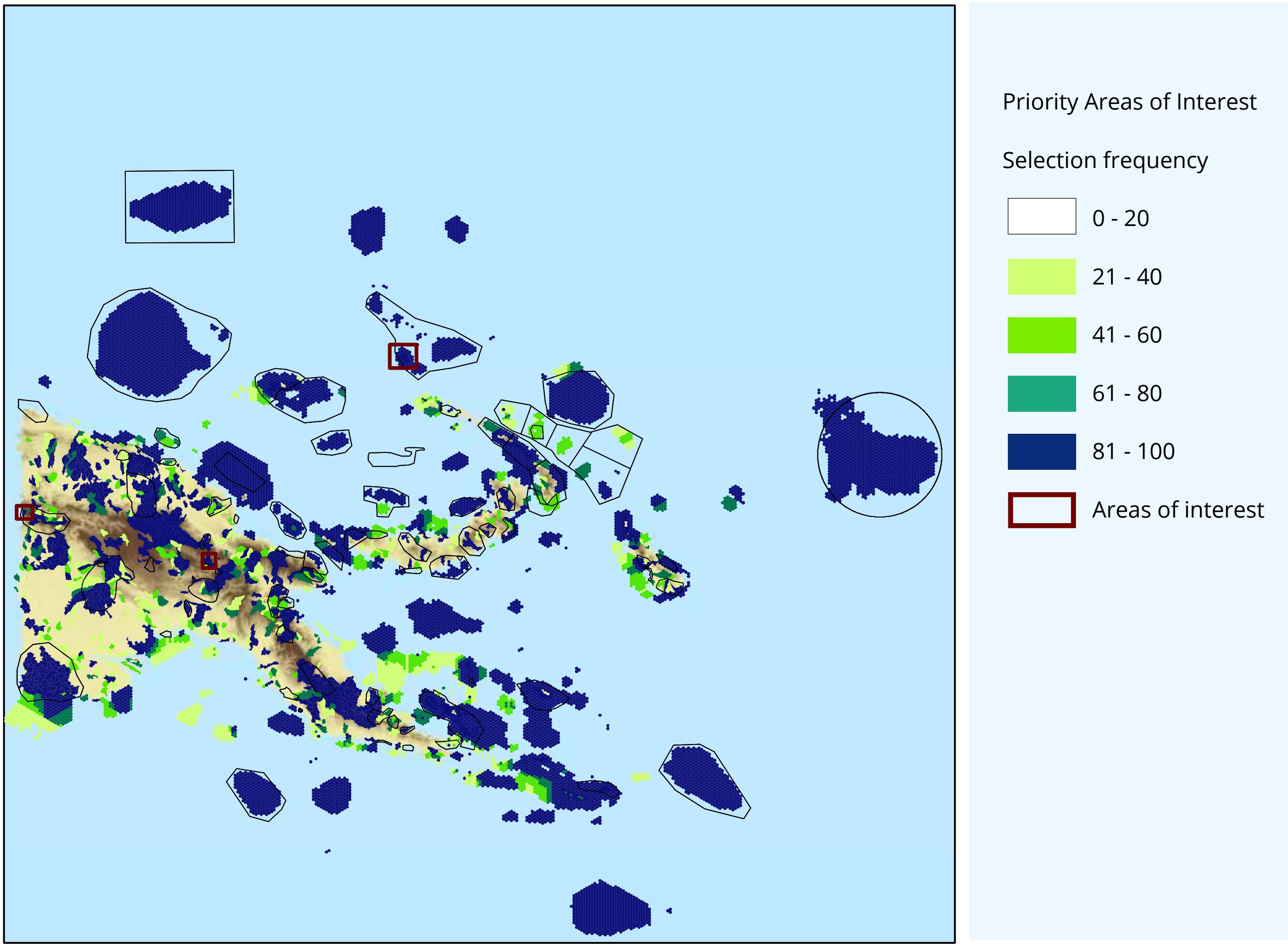

Golden-Mantled Tree Kangaroo with her young, PNG © Jean Thomas/ Tenkile Conservation Alliance

APPENDIX 6: TESTING THE CONSERVATION ASSESSMENT PRIORITIES COVERAGE FOR REPTILES

Nadya Dimitrova, Oliver Tallowin, Vanessa M Adams

The initial land-sea conservation assessment for Papua New Guinea (PNG) incorporated 81 land systems, 61 vegetation types, 170 restricted range endemic species, 28 critically endangered and endangered species, and areas that could act as climate refugia (see Table 1, Description of Conservation Features). At the time of preparation, data for reptiles were not available. Therefore, these taxa were not included. Since publication of the assessment, data has been made available via the IUCN Melanesian Reptile Working Group (2014) and in collaboration with Dr Oliver Tallowin.

Reptiles in PNG exhibit high species richness in the lowlands, contrasting with higher amphibian, bird and mammal richness in montane areas (Tallowin et al., 2017). Including reptiles in an updated Marxan analysis thus increased taxonomic coverage and the spatial richness disparity across PNG vertebrates. A total of 285 reptile species were incorporated, including 2 crocodiles, 251 lizards, 18 snakes, and 14 turtles (see A6 Table 1).



A6 Figure 1: Updated Marxan selection frequency, including reptiles. The three new high priority subcatchments selected are highlighted with red boxes. Areas of Interest – those conservation priorities selected by the government as priorities for immediate investment – are also mapped. The new priority subcatchments fall within existing AOIs and are therefore likely to receive conservation investment regardless of the analysis.

Initial Marxan analyses were constrained to just the terrestrial planning units. A BLM (boundary length modifier) of 0.05 was used after calibration for all scenarios in order to optimize the connectivity to costs ratio. The spatial distribution of priority areas identified by the initial terrestrial Marxan scenario(where reptile distributions are absent) and the updated Marxan analysis were statistically compared in two ways. The relationship between selection frequencies was analysed using Spearman's rank correlation. There was a significant correlation between the outputs of the two models ($n = 3,301$, $r_s = .9332$, $p < .0001$), i.e. the two distributions are not significantly different. Best scenarios were compared with Cohen's kappa statistic, which is a non-parametric test measuring agreement between independently rated sets. There was moderate agreement between the two best scenarios, $\kappa = .552$, $p < .001$, which is also an indicator of similarity.

The final Marxan analysis across both terrestrial and marine realms was also updated, incorporating the targets for all reptiles (5% target to be consistent with the assessment targets for IUCN range maps). This analysis was consistent with the preliminary testing; there were no significant changes in selection frequencies. Only three additional subcatchments across the entirety of PNG were selected with high selection frequencies in the updated Marxan analysis, relative to the original conservation priorities. The map of conservation priorities is shown in A6 Figure 1. The three additional subcatchments selected in the new marxan analysis (including reptiles) are shown in red boxes. We note that these three subcatchments are already contained within AOIs and therefore are likely to receive priority attention regardless of this change in the analysis.

A6 Table 1: List of reptile species incorporated in the assessment since the first publication of the conservation report.

Species	Type/Status
Bellatorias frerei	Lizards
Carettochelys insculpta	Turtles/ IUCN vulnerable
Carlia aenigma	Lizards
Carlia aramia	Lizards
Carlia bicarinata	Lizards
Carlia bomberai	Lizards
Carlia caesius	Lizards
Carlia diguliensis	Lizards
Carlia eothen	Lizards
Carlia fusca	Lizards
Carlia longipes	Lizards
Carlia luctuosa	Lizards
Carlia mysi	Lizards
Carlia pulla	Lizards
Carlia storri	Lizards
Chelodina gunaleni	Turtles
Chelodina novaeguineae	Turtles
Chelodina oblonga	Turtles
Chelodina parkeri	Turtles/ IUCN vulnerable
Chelodina pritchardi	Turtles/ IUCN endangered
Chelodina reimanni	Turtles
Chlamydosaurus kingii	Lizards
Corucia zebrata	Lizards
Crocodylus novaeguineae	Crocodiles

Species	Type/Status
Crocodylus porosus	Crocodiles
Cryptoblepharus aruensis	Lizards
Cryptoblepharus furvus	Lizards
Cryptoblepharus litoralis	Lizards
Cryptoblepharus novaeguineae	Lizards
Cryptoblepharus pallidus	Lizards
Cryptoblepharus poecilopleurus	Lizards
Cryptoblepharus richardsi	Lizards
Cryptoblepharus virgatus	Lizards
Cryptoblepharus xenikos	Lizards
Cryptoblepharus yulensis	Lizards
Crytoblepharus poecilopleurus	Lizards
Ctenotus robustus	Lizards
Ctenotus spaldingi	Lizards
Cyrtodactylus aaroni	Lizards
Cyrtodactylus arcanus	Lizards
Cyrtodactylus biordinis	Lizards
Cyrtodactylus boreoclivus	Lizards
Cyrtodactylus capreoloides	Lizards
Cyrtodactylus derongo	Lizards
Cyrtodactylus epiroticus	Lizards
Cyrtodactylus equestris	Lizards
Cyrtodactylus irianjayaensis	Lizards
Cyrtodactylus klugei	Lizards
Cyrtodactylus loriae	Lizards
Cyrtodactylus louisiadensis	Lizards

Species	Type/Status
Cyrtodactylus medioclivus	Lizards
Cyrtodactylus mimikanus	Lizards
Cyrtodactylus minor	Lizards
Cyrtodactylus murua	Lizards
Cyrtodactylus novaeguineae	Lizards
Cyrtodactylus papuensis	Lizards
Cyrtodactylus rex	Lizards
Cyrtodactylus robustus	Lizards
Cyrtodactylus salomonensis	Lizards
Cyrtodactylus sermowaiensis	Lizards
Cyrtodactylus serratus	Lizards
Cyrtodactylus tripartitus	Lizards
Cyrtodactylus zugi	Lizards
Dibamus novaeguineae	Lizards
Diporiphora bilineata	Lizards
Elseya branderhorsti	Lizards
Elseya novaeguineae	Lizards
Elseya rhodini	Lizards
Elseya schultzei	Lizards
Emoia aenea	Lizards
Emoia atrocostata	Lizards
Emoia aurulenta	Lizards
Emoia battersbyi	Lizards
Emoia baudini	Lizards
Emoia bismarckensis	Lizards
Emoia bogerti	Lizards
Emoia brongersmai	Lizards
Emoia caeruleocauda	Lizards
Emoia callisticta	Lizards
Emoia coggeri	Lizards
Emoia cyanogaster	Lizards
Emoia cyanura	Lizards
Emoia cyclops	Lizards
Emoia digul	Lizards
Emoia flavigularis	Lizards
Emoia guttata	Lizards
Emoia impar	Lizards
Emoia irianensis	Lizards
Emoia jakati	Lizards
Emoia jamur	Lizards
Emoia klossi	Lizards
Emoia kordoana	Lizards
Emoia kuekenthali	Lizards
Emoia longicauda	Lizards
Emoia loveridgei	Lizards
Emoia maxima	Lizards
Emoia mivarti	Lizards

Species	Type/Status
Emoia montana	Lizards
Emoia nigra	Lizards
Emoia obscura	Lizards
Emoia oribata	Lizards
Emoia pallidiceps	Lizards
Emoia paniai	Lizards
Emoia physicae	Lizards
Emoia physicina	Lizards
Emoia popei	Lizards
Emoia pseudocyanura	Lizards
Emoia pseudopallidiceps	Lizards
Emoia reimschisseli	Lizards
Emoia sorex	Lizards
Emoia submetallica	Lizards
Emoia tetrataenia	Lizards
Emoia tropidolepis	Lizards
Emoia veracunda	Lizards
Emydura subglobosa	Lizards
Eugongylus albofasciolatus	Lizards
Eugongylus rufescens	Lizards
Eugongylus unilineatus	Lizards
Eutropis multifasciata	Lizards
Foija bumui	Lizards
Gehyra baliola	Lizards
Gehyra barea	Lizards
Gehyra dubia	Lizards
Gehyra insulensis	Lizards
Gehyra leopoldi	Lizards
Gehyra marginata	Lizards
Gehyra membranacruralis	Lizards
Gehyra oceanica	Lizards
Gehyra papuana complex	Lizards
Gehyra rohan	Lizards
Gehyra serraticauda	Lizards
Gekko monarchus	Lizards
Gekko vittatus	Lizards
Geomyersia glabra	Lizards
Glaphyromorphus crassicaudus	Lizards
Glaphyromorphus nigricaudis	Lizards
Gowidon temporalis	Lizards
Hydrosaurus amboiensis	Lizards
Hypsilurus auritus	Lizards
Hypsilurus binotatus	Lizards
Hypsilurus bruijnii	Lizards
Hypsilurus capreolatus	Lizards
Hypsilurus dilophus	Lizards
Hypsilurus geelvinkianus	Lizards

Species	Type/Status
Hypsilurus hikidanus	Lizards
Hypsilurus longi	Lizards
Hypsilurus macrolepis	Lizards
Hypsilurus magnus	Lizards
Hypsilurus modestus	Lizards
Hypsilurus nigrigularis	Lizards
Hypsilurus ornatus	Lizards
Hypsilurus papuensis	Lizards
Hypsilurus schoedei	Lizards
Hypsilurus schultzewestrumi	Lizards
Lamprolepis smaragdina	Lizards
Lepidodactylus browni	Lizards
Lepidodactylus guppyi	Lizards
Lepidodactylus lugubris	Lizards
Lepidodactylus magnus	Lizards
Lepidodactylus mutahi	Lizards
Lepidodactylus novaeguineae	Lizards
Lepidodactylus orientalis	Lizards
Lepidodactylus pulcher	Lizards
Lepidodactylus pumilus	Lizards
Lepidodactylus woodfordi	Lizards
Lialis burtonis	Lizards
Lialis jicari	Lizards
Lipinia albodorsalis	Lizards
Lipinia cheesmanae	Lizards
Lipinia longiceps	Lizards
Lipinia noctua	Lizards
Lipinia nototaenia	Lizards
Lipinia occidentalis	Lizards
Lipinia pulchra	Lizards
Lipinia rouxi	Lizards
Lipinia septentrionalis	Lizards
Lipinia venemai	Lizards
Lobulia alpina	Lizards
Lobulia brongersmai	Lizards
Lobulia elegans	Lizards
Lobulia glacialis	Lizards
Lobulia stellaris	Lizards
Lobulia subalpina	Lizards
Lygisaurus curtus	Lizards
Lygisaurus macfarlani	Lizards
Lygisaurus novaeguineae	Lizards
Nactus acutus	Lizards
Nactus kunan	Lizards
Nactus multicarinatus	Lizards
Nactus sphaerodactylodes	Lizards
Nactus vankampeni	Lizards

Species	Type/Status
Papuascincus morokanus	Lizards
Papuascincus stanleyanus	Lizards
Pelochelys bibroni	Turtles/ IUCN vulnerable
Pelochelys signifera	Turtles
Prasinohaema flavipes	Lizards
Prasinohaema prehensicauda	Lizards
Prasinohaema semoni	Lizards
Prasinohaema virens	Lizards
Sphenomorphus aignanus	Lizards
Sphenomorphus annectens	Lizards
Sphenomorphus anotus	Lizards
Sphenomorphus aruensis	Lizards
Sphenomorphus brunneus	Lizards
Sphenomorphus cinereus	Lizards
Sphenomorphus concinnatus	Lizards
Sphenomorphus cranei	Lizards
Sphenomorphus darlingtoni	Lizards
Sphenomorphus derooyae	Lizards
Sphenomorphus forbesii	Lizards
Sphenomorphus fragilis	Lizards
Sphenomorphus fragosus	Lizards
Sphenomorphus fuscolineastus	Lizards
Sphenomorphus granulatus	Lizards
Sphenomorphus jobiensis	Lizards
Sphenomorphus latifasciatus	Lizards
Sphenomorphus leptofasciatus	Lizards
Sphenomorphus longicaudatus	Lizards
Sphenomorphus loriae	Lizards
Sphenomorphus louisiadensis	Lizards
Sphenomorphus maindroni	Lizards
Sphenomorphus meyeri	Lizards
Sphenomorphus	Lizards
microtympanus	Lizards
Sphenomorphus mimikanus	Lizards
Sphenomorphus minutus	Lizards
Sphenomorphus muelleri	Lizards
Sphenomorphus neuhaussi	Lizards
Sphenomorphus nigriventris	Lizards
Sphenomorphus nigrolineatus	Lizards
Sphenomorphus oligolepis	Lizards
Sphenomorphus papuae	Lizards
Sphenomorphus pratti	Lizards
Sphenomorphus rufus	Lizards
Sphenomorphus schultzei	Lizards
Sphenomorphus simus	Lizards
Sphenomorphus solomonis	Lizards

Grass snake, PNG © Jackal Photography/ Shutterstock

Species	Type/Status
Sphenomorphus tanneri	Lizards
Sphenomorphus taylori	Lizards
Sphenomorphus transversus	Lizards
Sphenomorphus undulatus	Lizards
Sphenomorphus wolfi	Lizards
Sphenomorphus wollastoni	Lizards
Sphenomorphus woodfordi	Lizards
Tiliqua gigas	Lizards
Toxicocalamus preussi	Snakes
Toxicocalamus spilolepidotus	Snakes
Toxicocalamus stanleyanus	Snakes
Tribolonotus annectens	Lizards
Tribolonotus blanchardi	Lizards
Tribolonotus brongersmai	Lizards
Tribolonotus gracilis	Lizards
Tribolonotus novaeguineae	Lizards
Tribolonotus ponceleti	Lizards
Tribolonotus pseudoponceleti	Lizards
Tropidonophis aenigmaticus	Snakes
Tropidonophis dahlii	Snakes
Tropidonophis dolasii	Snakes
Tropidonophis doriae	Snakes
Tropidonophis elongatus	Snakes
Tropidonophis hypomelas	Snakes
Tropidonophis mairii	Snakes
Tropidonophis mcdowelli	Snakes
Tropidonophis montanus	Snakes
Tropidonophis multiscutellatus	Snakes
Tropidonophis novaeguineae	Snakes
Tropidonophis parkeri	Snakes
Tropidonophis picturatus	Snakes
Tropidonophis statistictus	Snakes
Tropidonophis truncatus	Snakes
Varanus beccarii	Lizards
Varanus boehmei	Lizards
Varanus bogerti	Lizards
Varanus doreanus	Lizards
Varanus finschi	Lizards
Varanus indicus	Lizards
Varanus jobiensis	Lizards
Varanus kordensis	Lizards
Varanus macraei	Lizards
Varanus panoptes	Lizards
Varanus prasinus	Lizards
Varanus reisingeri	Lizards
Varanus salvadorii	Lizards
Varanus scalaris	Lizards
Varanus semotus	Lizards
Varanus telenesetes	Lizards

References:

Tallowin, O., Allison, A., Algar, A.C., Kraus, F. and Meiri, S., 2017. Papua New Guinea terrestrial - vertebrate richness: elevation matters most for all except reptiles. Journal of Biogeography, 44(8), pp.1734-1744.

APPENDIX 7. GAP ANALYSIS OF SCHEDULING SHORT, MEDIUM AND LONG-TERM ACTIONS BASED ON THE AREAS OF INTEREST (AOIS)

Nadya Dimitrova, Vanessa M Adams

With 28 million hectares, Papua New Guinea (PNG) has the 3rd largest tropical rainforest in the world and great biodiversity (a lot of which is endemic species), which is threatened by habitat loss due to logging and conversion for agriculture (Bryan and Shearman 2015). Only 4% of the terrestrial area of Papua New Guinea (PNG) is currently protected; however, the priority areas identified in this conservation assessment identify conservation priorities that cover 17% of the land and sea area of PNG. This level of protection is in line with target 11 of the Convention on Biological Diversity (CBD 2010), which the country has made a commitment to meet by 2020.

Increasing protection from 4% to 17% of land will require incremental changes in the reserve network over a period of years; during this time changes in the distribution of land available (e.g. due to clearing) and conservation features (e.g. locations of endangered species) may change. Therefore, scheduling conservation actions is important to ensure that incremental increases in protection of land over time result in a network that meets conservation targets. During expert workshops (Appendix 3), a subset of the conservation priorities identified within the assessment were mapped as Areas of Interest that should be first targeted for conservation investment (Figure 2, Areas of Interest (AOIs)). Within these areas of interest a set of national and provincial priorities (A and A1) were identified for immediate action (Figure 2, Areas of Interest (AOIs)).

The Areas of Interest will guide short and medium term conservation action by the PNG Government and are a schedule for action. It is therefore critical to understand which targets will be met if conservation is successfully implemented within these areas, and for which targets there will be shortfalls that must be subsequently targeted. Scheduling actions will inherently require updated spatial priorities. To address these issues, we provide a gap analysis of the targets PNG will meet if it reserves conservation areas under three scheduling scenarios described below. The gap analyses also incorporate reptile distributions which were not available when the initial assessment was being completed. Their inclusion is relevant, because unlike the species used for the previous models, reptile species richness is highest in lowland areas (Tallowin et al., 2017) (see Appendix 6 for details). Data for the distribution of reptiles was provided by the IUCN Melanesian Reptile Working Group (2014) and in collaboration with Dr Oliver Tallowin.

The following scenarios were considered (the areas included can be seen in A7 Figure 1):

1. Scenario 1: reserve only the 12 areas selected in a workshop as immediate priorities on a national (subset A, consisting of 12 areas) and provincial scale (subset A1, including 9 areas).
2. Scenario 2: reserve the areas in scenario 1 plus 9 areas identified as key protected areas in a follow-up workshop (Hunstein, Kamali, Lake Kutubu, Libano, Mangalas, Maza, Mt Toricelli, Tonda, and Yus).
3. Scenario 3: reserve the areas in scenario 2 plus the remaining areas of the initially identified Areas of Interest (AOIs).

As a further step in the analysis, we considered which areas should be prioritized next if all of the areas in scenario 3 become protected. To do this we updated the full land sea Marxan analysis, including reptiles, locked in all areas for scenario 3 (i.e. assumed they were successfully protected) and then identified additional areas that need to be protected to meet all conservation targets (long term action).

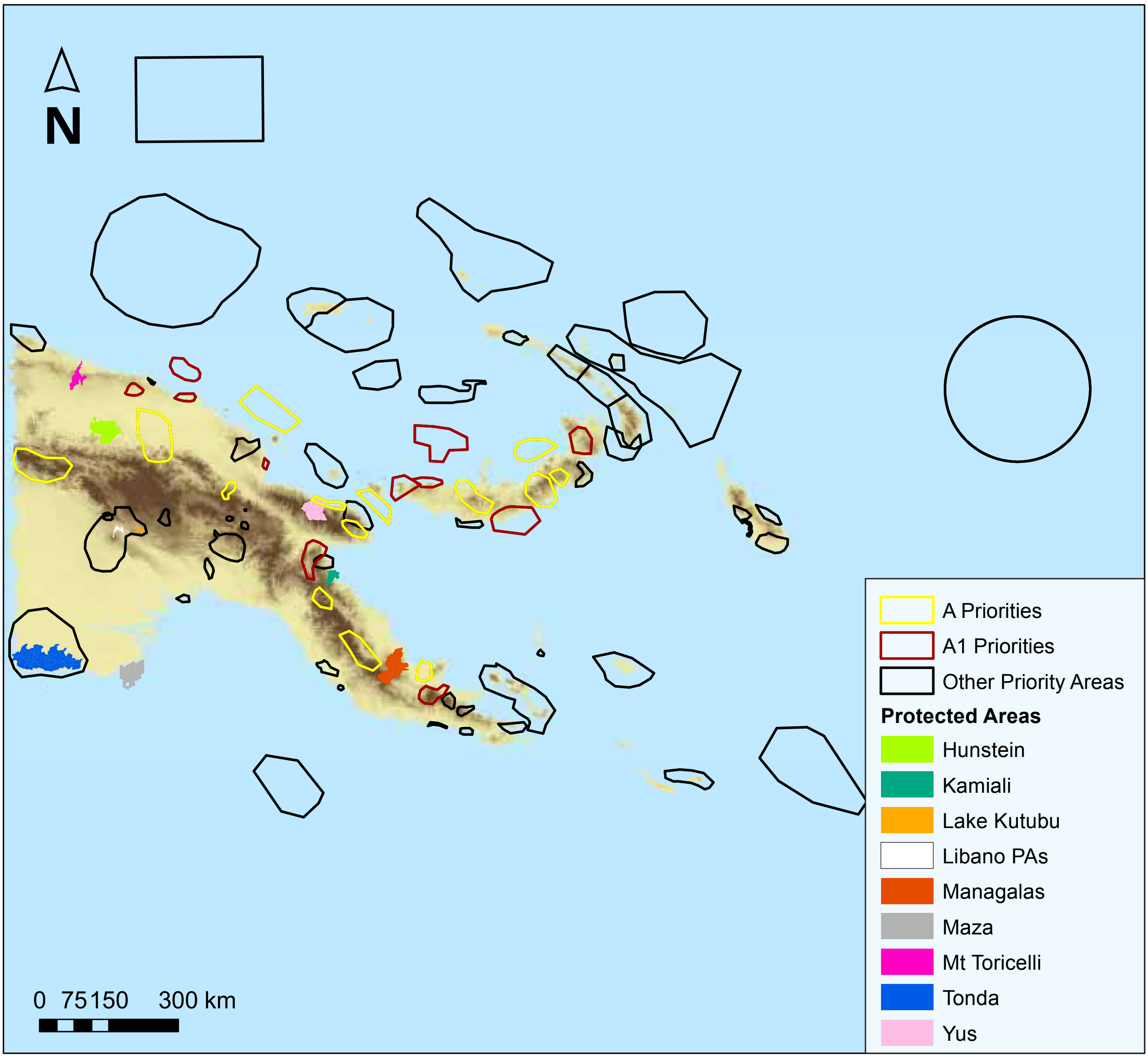
The results of the gap analysis are summarized in A7 Table 1. For each feature (e.g. a single species, type of vegetation, etc.), a target was considered as being met if >90% of the target area for that feature was being held for protection. Table 1 shows what percent of features in the 6 categories meet their targets under the respective scenarios. Protection targets are the same as in the initial model with the added category of reptiles having a 5% protection goal in order to be consistent with the previously set target for IUCN maps. An analysis of ecoregion protection was also undertaken and the results can be seen in A7 Table 2.

Key findings of the gap analysis include:

1. Scenario 1 (immediate term action) – if only A and A1 priority areas are protected (and none of the current protected areas are found to be effective), there are major gaps in most conservation targets, and only two ecoregions are well represented.

2. Scenario 2 (immediate term action) – if only A and A1 priority areas are protected in addition to the 9 currently protected areas, about a third of all features will meet their conservation targets. This is an improvement to Scenario 1 (excluding current protected areas), but major gaps in targets remain. Restricted range endemic (RRE) fauna are particularly underrepresented, with only about 20% of species meeting their targets (A7 Table 1). Most ecoregions would be inadequately protected, with the exception of Northeastern Island, Southeast Peninsula, and Northern New Guinea, which will have >10% representation (A7 Table 2).

3. Scenario 3 (medium term action) – all ecoregions will be well represented if all identified priority areas as well as currently protected areas are included in a reserve network (A7 Table 2). About 60% of all features will meet their targets (Table 1). RRE species and Endangered and critically endangered fauna remain under represented, with little gains made by protecting the additional Areas of Interest. Targeting their restricted locations for future protection is a critical long-term goal to fill these conservation gaps.



A7 Figure 1. Areas incorporated in the three scenarios of the report. In scenario 1 only immediate priorities on a national (A priorities) and provincial (A1 priorities) scale are being protected. Scenario 2 includes these plus 9 key protected areas as well. Scenario 3 includes all of the above as well as the remainder of the initially identified priority areas.

A7 Table 1. Percent of features for which more than 90% of the target area are protected under the three scenarios.

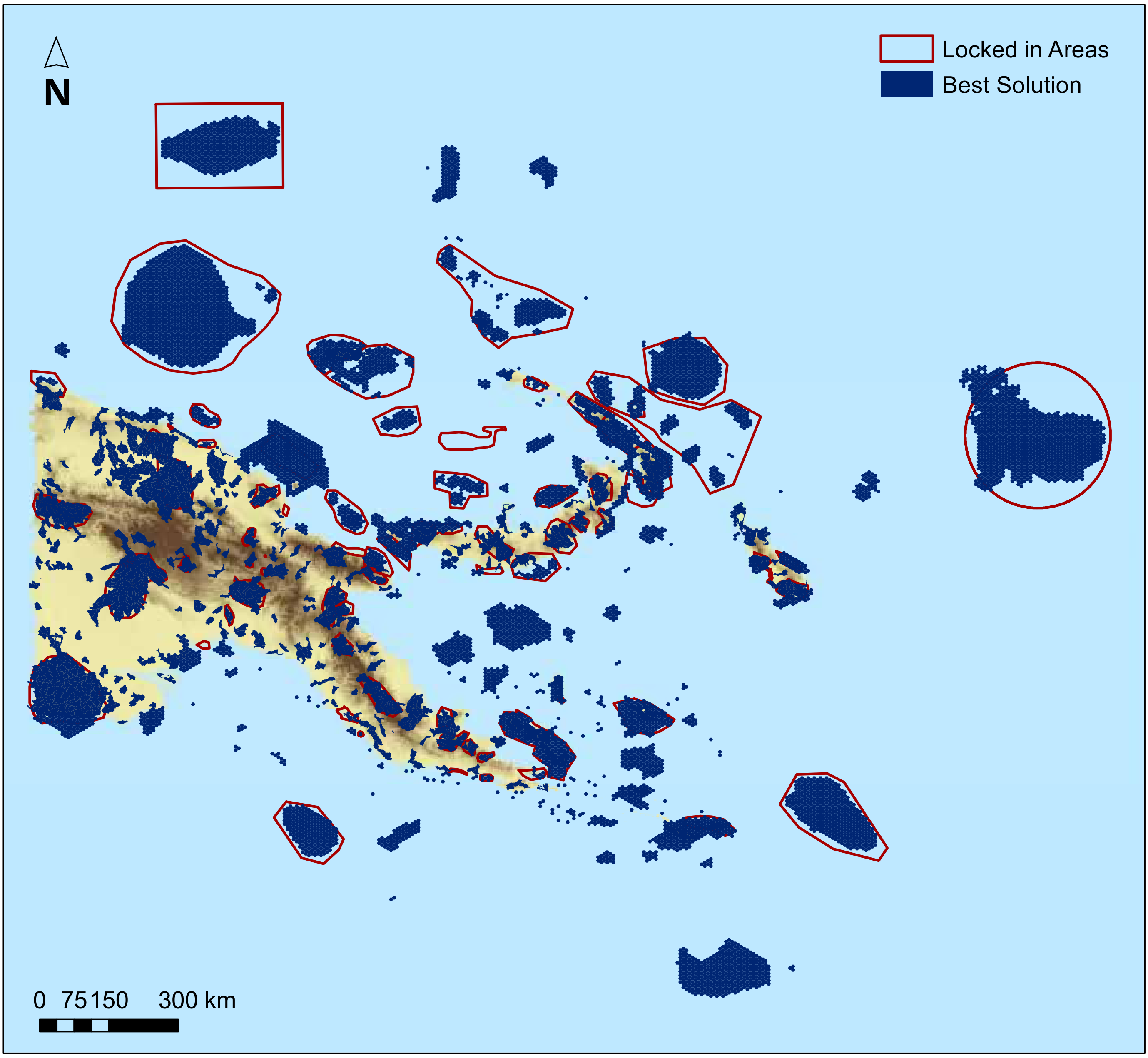
		Percent of targets met		
Category	Protection Target	Scenario 1	Scenario 2	Scenario 3
Climate Refugia	5%	100	100	100
Endangered and Critically Endangered Fauna	5%	31	44	44
Land Systems	10%	35	52	76
Reptiles	5%	39	46	64
Restricted Range Endemic Fauna	50%	13	20	29
Vegetation	10%	23	47	93
All features	n/a	31	40	58

A7 Table 1. Percent of features for which more than 90% of the target area are protected under the three scenarios.

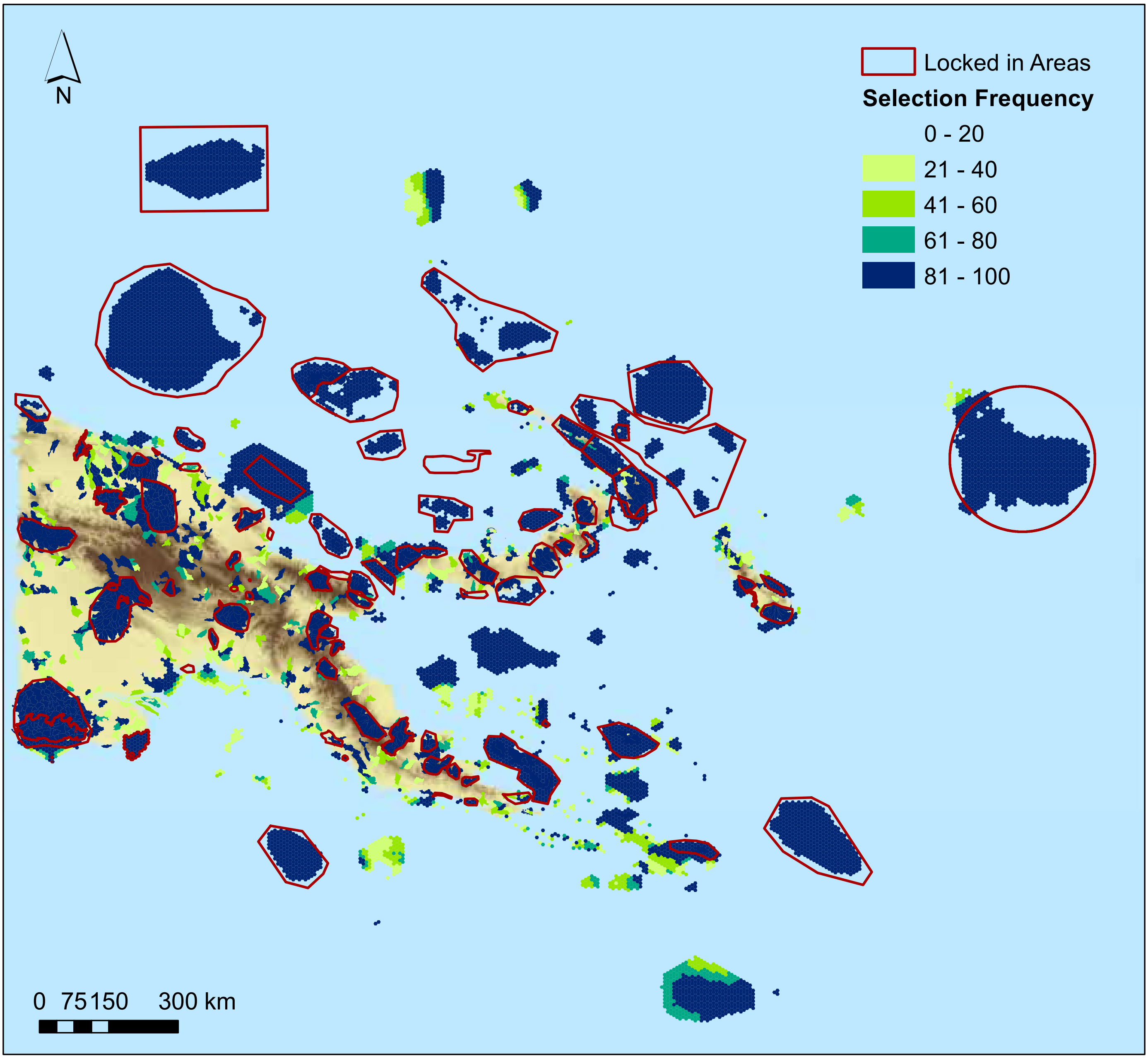
	Percent of ecoregions reserved		
Ecoregion	Scenario 1	Scenario 2	Scenario 3
Admiralty Islands	0	0	100
Bougainville	0	0	30
Central Range	7	8	16
Northeastern Island	26	26	43
Northern New Guinea	7	11	15
Southeast Peninsula	12	17	19
Southeastern Islands	0	0	17
Southern New Guinea	0	4	18
Trobirand Islands	0	0	91
Everything else	9	12	24

To identify long-term spatial priorities to fill these remaining gaps, the full land sea Marxan analysis was run for scenario 3 (A7 Figures 2, 3). If a best scenario solution (A7 Figure 2) guides action, then all selected areas need to be protected in order to meet conservation goals. If using selection frequency to guide action (A7 Figure 3), areas that have been selected more often should be prioritized, while ones with lower selection frequencies are more interchangeable and provide options that can be protected based on management strategies, land availability, and other selection criteria.

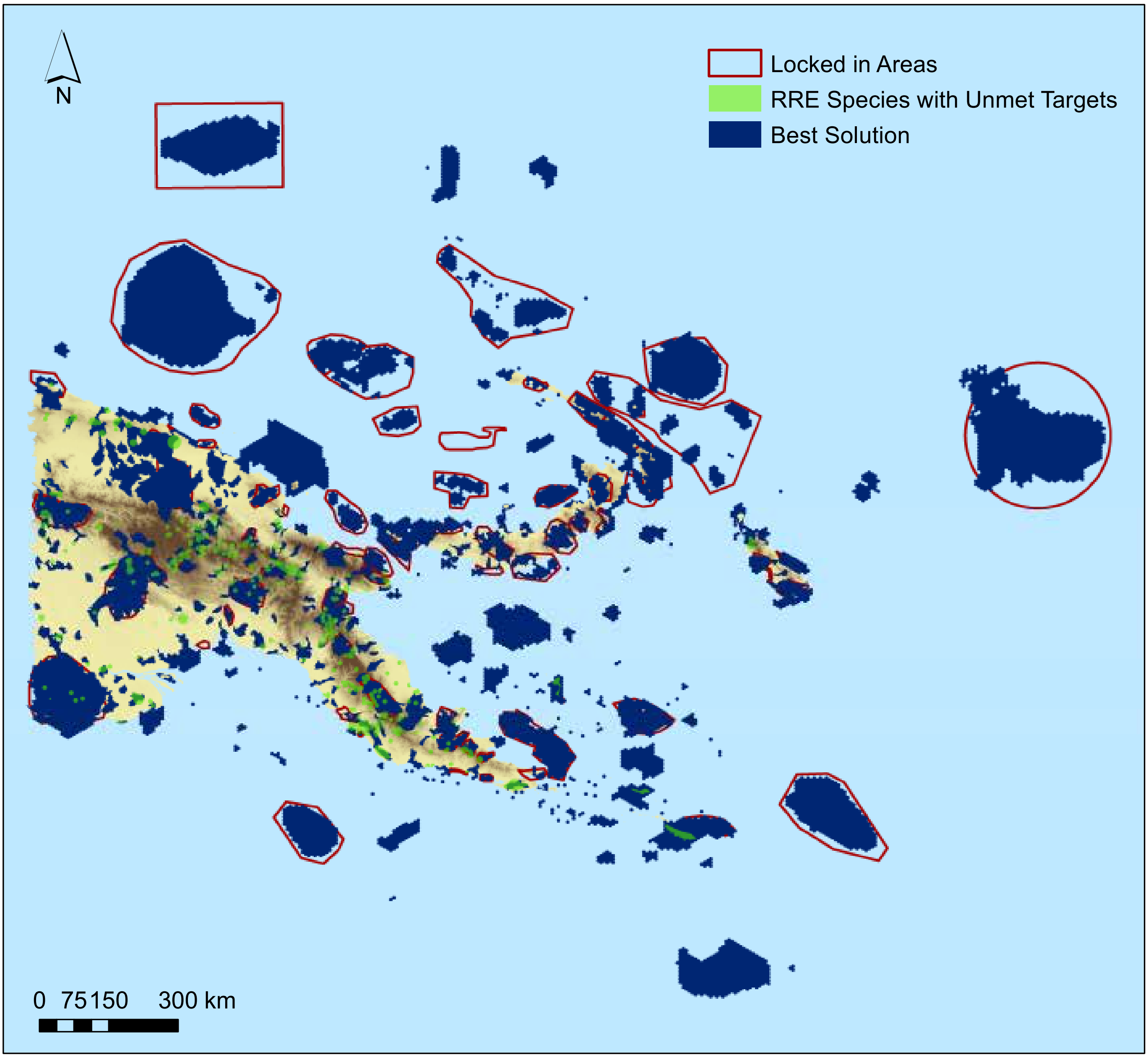
It should be noted that as actions are scheduled and implemented, in order to provide accurate information about what targets have been met and which areas should be prioritized next, Marxan should be updated on a regular basis. Running the scenario in Marxan illustrates why protecting RRE fauna is an important long-term action, as many of the areas selected for protection overlap with the distributions of RRE species that haven't met their targets (A7 Figure 4).



A7 Figure 2. Best solution for scenario 3 – all priority areas (including A and A1) plus 9 key protected areas are locked in. If this solution is used to guide policy, all of the selected areas on the map need to be protected simultaneously in order to meet conservation goals.



A7 Figure 3. Selection frequency for scenario 3 - all priority areas (including A and A1) plus 9 key protected areas are locked in. Areas with higher selection frequencies are a priority for meeting targets and ones that have been selected less often are more interchangeable.



A7 Figure 4. Selection frequency for scenario 3, including the distributions of restricted range endemic species which haven't met their conservation protection targets

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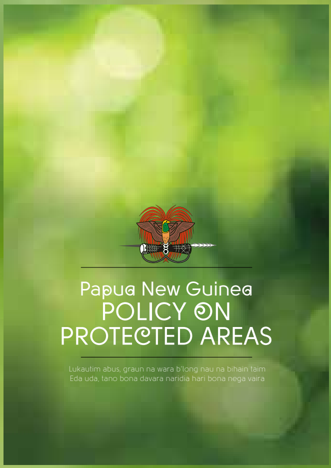

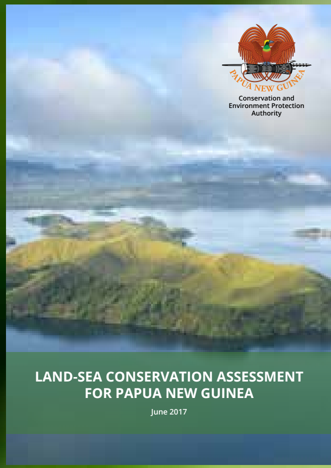

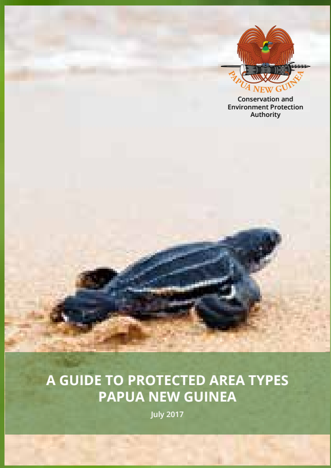

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