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May 2007
TNC Pacific Island Countries
Report No 1/07

Biodiversity Planning for Palau's Protected Areas Network

An Ecoregional Assessment

Prepared by:
David Hinchley, Geoff Lipsett-Moore, Stuart Sheppard,
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Supported by:

Ngatpang State, Sonsorol State and Hatohobei State

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Contents

List of Tables

List of Figures

List of Appendices

List of Acronyms

BLM	Boundary Length Modifier
CRRF	Coral Reef Research Foundation
GIS	Geographic Information System
IBA	Important Bird Area
IMARS/USF	Institute for Marine Remote Sensing, University of South Florida
MARXAN	Marine Reserve Design using Spatially Explicit Annealing
MRD	Ministry of Resources and Development
PALARIS	Palau Automated Land and Resources Information System
PAN	Palau's Protected Areas Network
PCS	Palau Conservation Society
PICRC	Palau International Coral Reef Center
SCRFA	Society for the Conservation of Reef Fish Aggregations
SPOT	Spatial Portfolio Optimization Tool
TNC	The Nature Conservancy

EXECUTIVE SUMMARY

In November 2003 a landmark piece of legislation, the Protected Areas Network Act was passed by the Olbiil Era Kelulau (Palau National Congress) and signed into law by President Tommy E. Remengesau, Jr. The Act provides a framework for Palau's national and State governments to collaborate to establish a nationwide network of marine and terrestrial protected areas that will protect areas of biodiversity significance, important habitats, and other valuable resources essential for the future social, cultural, economic, and environmental stability and health of Palau. This legislation creates a framework by which the National and State governments can work together to build on the existing suite of protected areas and further develop a protected areas network that meets the dual objectives of protecting the country's rich biodiversity and sustainably managing its natural resources.

This ecoregional assessment report provides a starting point for discussion between National and State governments to progress these objectives. The document provides a synthesis of current biodiversity knowledge in Palau and provides initial guidance for the development and implementation of a nationwide network of marine and terrestrial protected areas. This report outlines a number of potential protected areas scenarios that aim to meet biodiversity conservation goals identified by local stakeholders from the private sector and National and State governments. The areas identified in the various protected areas network scenarios do not necessarily represent actual areas that should be designated and/or managed, rather, these scenarios can be used as a starting point for community consultations and discussions at the State level to help progress the development of the protected areas network.

During a consultative expert workshop in 2002, a first iteration summarizing existing biodiversity data and assessing protected areas network scenarios was completed. Due to limited available data, only twenty-four "biodiversity targets" (e.g., ecosystems, habitats, species, and special areas such as turtle nesting or spawning aggregation areas, etc.) were used in this initial analysis. The results of this first iteration did show that there was likely to be ample scope for meeting biodiversity conservation goals under a variety of different scenarios, based on mapping of biodiversity targets at that time. It was also recognized that more work was required to improve the quality of existing data sets and that other key data sets needed to be derived to effectively inform the PAN development.

In May 2006 a second iteration assessment, consisting of two workshops, was conducted using improved and more comprehensive spatial data. The second iteration embodied a ridges to reefs approach including terrestrial, freshwater and marine systems. These workshops sought to: (1) develop an agreed set of protected area design principles, stratification, conservation targets, goals, and cost surface (2) to provide a range of protected areas network scenarios as a guide of possible PAN options for review by workshop participants.

The first expert workshop required the completion of five major tasks. First, a draft set of design principles, established to guide decisions about the most important areas for inclusion in a protected areas network was reviewed and finalized by the participants. Second, a draft stratification, to ensure that protected areas sampled the full range of environmental and geographic variation for Palau was also revised and refined. Third, the best available biodiversity and socio-economic spatial information was reviewed and refined by the experts. Each element of biodiversity under consideration was termed a "biodiversity target" (e.g., ecosystems, habitats, species, and special areas such as turtle nesting or spawning aggregation areas). A total of 39 targets were used in the analysis. Of these, 16 were marine or coastal systems, 10 were terrestrial systems, 3 were freshwater aquatic, 4 were aggregation areas of multiple species, 5 were focal areas for individual species (hawksbill turtle, green turtle, dugong, saltwater crocodile, fruit bat) and one was a coastline feature. Fourth, conservation goals were established for all 39 targets and agreed on by workshop participants. Finally, experts developed a "cost surface" for the process, where socioeconomic data were used to determine those areas most favourable and least favourable for the establishment of protected areas. Following the completion of the first workshop, MARXAN (a conservation planning tool) was used to develop a number of protected area network design scenarios.

The second expert workshop reviewed the scenarios generated by MARXAN. The general consensus from workshop participants was that MARXAN provided a useful synthesis of many complex and often competing values. In all scenarios, the areas identified from the MARXAN analysis were important for protection and management. In some cases the MARXAN scenarios highlighted areas that were not previously recognized as having particular importance. In other instances, the scenarios reinforced current knowledge by participants that existing and proposed protected areas are capturing Palau's most biologically important areas. Most concerns about the scenario outputs related to the development of the cost surface and related land management issues. There were some concerns about large areas identified simply as "protected areas" as these areas often encompass several different levels or types of management (e.g., The Rock Islands Southern Lagoon Management Area is designated as a protected area, but within this there are zones with differing levels of protection). Also, traditionally managed areas, which have existed for hundreds of years, were not adequately considered in the scenarios. Additional data gaps and solutions to fill these were also identified.

A key outcome from the second workshop was that more local information from the States needed to be incorporated in the MARXAN analysis process. It was recommended that a finer scale analysis be run for each State incorporating local values, perspectives, and priorities and that this would provide an opportunity to harmonize National and State views. Analysis at the State level would look more closely at local socio-economic, cultural and resource management needs together with biodiversity conservation aims and objectives. It was also recognized that MARXAN could be used as a tool to periodically evaluate progress towards biodiversity and PAN goals at State and National levels.

Staff from the Palau International Coral Reef Center and The Nature Conservancy presented a synopsis of the workshop results to the Palau National Congress' House of Delegates in May, 2006. The Delegates felt that the protected areas network scenarios were extremely useful to guide and assist in the development of Palau's protected areas network and echoed the sentiments of the workshop participants by suggesting that subsequent State-specific analyses were needed to support the concerns and desires of each State.

The critical next step is to use the scenarios developed in this process to promote wider discussion amongst local communities, State and traditional leaders and the National government on areas that might be considered for inclusion in the Protected Areas Network. The national scenarios provide a powerful tool and guide for initial discussion of options with the States. The scenarios also help to inform the development of a network of larger contiguous areas rather than less viable small isolated protected areas.

INTRODUCTION

OBJECTIVES

The primary aim of this document is to provide a synthesis of current biodiversity knowledge to contribute towards the planning and implementation of a nationwide network of marine and terrestrial protected areas for Palau. This report provides a number of scenarios that give an overview of options for areas that could be included in the Protected Areas Network to meet biodiversity conservation goals. It is not intended that the areas presented represent actual areas that should be designated and managed as protected areas but this information can be used in the processes of community consultation and discussion at the State level to help progress the development of the Protected Areas Network.

Although there are already 30 conservation areas of various types in Palau, ranging from traditional closures or "bul" to State and national conservation areas protected by legislation, most of these have been protected primarily for resource management purposes. For example, a reef may be closed for a couple of years to allow it to recover from over fishing, while other areas, such as spawning aggregation sites are closed or have restrictions on resource extraction on a permanent basis for specific times of the year. Many of these "managed areas" are a response to an immediate problem or the management of a very specific element of biodiversity. However, to date there has been little consideration of comprehensive, adequate and representative protected areas planning where all elements of biodiversity are effectively considered for the whole of Palau.

In November 2003 a landmark piece of legislation, the Protected Areas Network Act was passed by the Olbiil Era Kelulau (Palau National Congress) and signed into law by President Tommy E. Remengesau, Jr. The Act provides a framework for Palau's national and State governments to collaborate to establish a nationwide network of terrestrial and marine protected areas that will protect areas of biodiversity significance, important habitats and other valuable resources that are essential for the future social, cultural, economic, and environmental stability and health of Palau.

This provides an opportunity for the national and State governments to work together to build on the existing suite of protected areas to develop a protected areas network that meets the dual objectives of protecting the country's terrestrial and marine biodiversity, in concert with sustainably managing the natural resources. This ecoregional assessment report provides a starting point for discussion between national and State governments to progress these dual objectives. The Protected Areas Network Act allows for designation of protected areas under a variety of categories, ranging from strict protection through to multiple use management.

At the same time there are significant development challenges facing Palau, particularly on the largest island of Babeldaob, where a new road around the island is opening up the island for easier access and development opportunities. Information on areas that are important for biodiversity protection and management will help to guide land-use planning to ensure that development is sensitive to the both the terrestrial and marine environments of Palau.

OVERVIEW OF PALAU'S BIODIVERSITY

Considered one of the "Seven Underwater Wonders of the World," Palau has the highest levels of marine and terrestrial biodiversity within Micronesia, and is on the north-eastern margin of the area called "the Coral Triangle" which has the highest diversity of shallow-water marine species in the world (Green and Mous 2006). Although Palau has slightly fewer species than found in the coral triangle, the diversity of marine habitats found within the relatively small area of the Palauan archipelago is probably as great as would be found anywhere in the world. Palau supports more than 350 species of hard coral, 200 species of soft coral, over 300 species of sponges and more than 1,300 species of reef fish (Anon 2002). Its waters are also home to endangered and vulnerable species such as the dugong, saltwater crocodile, hawksbill and green turtles, and giant clams. Palau also has more than 60 marine lakes, of which five are home to stingless jellyfish that have evolved in these unique ecosystems.

Terrestrially, Palau is the most biodiverse country in Micronesia. Though the rich biodiversity of its vulnerable forests has yet to be fully documented, Babeldaob, the largest island, is home to more than 800 species of vascular plants, eight endemic bird species and a Palauan variety of the Marianas fruitbat (Anon 2002).

The immediate threats to Palau's biodiversity are inappropriate natural resources use due to tourism related activities and development, internal population movements, the drive for economic development to maintain the current high standard of living, and climate-related coral bleaching. Over-exploitation of nearshore marine resources is a significant issue, with commercial operations compounding subsistence use. While nature conservation efforts have historically focused on the coastal marine threats, the construction of a 52-mile road around Babeldaob island, the largest island in Palau and the second largest in Micronesia, is producing the greatest immediate environmental challenge. The road is opening up the island to development activities and internal population movements that will impact on the relatively undisturbed forests and their biodiversity. These land-use activities will also impact the adjacent coastal reef areas. Proposals currently include major resort hotels, golf courses, casinos, a new port, and a free trade zone. Compounding these immediate threats, Palau's reefs have also suffered high levels of coral bleaching and mortality following the 1998 El Niño Southern Oscillation (ENSO) event. These ENSO events are expected to increase in frequency and intensity in coming years, posing a serious threat to the biodiversity of coral reefs in Palau.

TNC'S ECOREGIONAL ASSESSMENT METHODOLOGY

In its 50-year history, The Nature Conservancy (TNC) has continually adapted and expanded its conservation strategies, and within the past 10 years has adopted a framework for conservation that places emphasis on the conservation of all communities and ecosystems (not just the rare ones) and emphasizes conservation at multiple levels of biological organization (Beck et al. 2000). A key part of this approach is identifying the sites that must be conserved, managed, or restored to represent the entire diversity of the area in viable populations, communities, and ecosystems. A general description of this planning process is provided in The Nature Conservancy's "Designing a Geography of Hope" (Groves et al. 2000). This assessment is based on the TNC approach and uses the following steps:

1. Identification of biodiversity targets (species, communities and ecosystems that represent the biodiversity of the region)
2. Mapping of the occurrences/distribution of biodiversity targets, together with a database of information related to each target
3. Identification of conservation goals for each biodiversity target (i.e. what is needed to ensure that each biodiversity target is conserved in the future - considering area needed for viability, scale, and ecosystem function)
4. Identification of areas of high biodiversity value (e.g. areas that support multiple targets, rare species, and those that are important to maintain ecological processes)
5. Analysis of threats and causes of threat to high biodiversity areas and targets

The ultimate goal of ecoregional planning efforts is the identification of a network of areas of biodiversity significance that collectively, if conserved or managed, will ensure the maintenance of a regions biodiversity. Groves *et. al.* (2000) identified six principles that are required for an effective design:

1. The portfolio of conservation and managed sites represents all system targets.
2. Multiple examples of all conservation targets should be represented across the diversity of environmental gradients in the ecoregion.
3. Priority is given to system targets during the site selection process as these areas are likely to contain multiple species targets.

4. Areas that contain high-quality examples from multiple environments (marine, aquatic and terrestrial) are also given priority.
5. Areas of biodiversity significance should be functional – maintain size, condition and landscape/seascape context - within the natural range of variability of the conservation targets.
6. The assemblage of areas of biodiversity significance should capture all targets.

METHODS

OVERVIEW OF THE PROCESS

Because Palau's environment is still relatively intact compared with many other countries, there is a wide range of options for the design (location, size, and configuration) of protected areas that could potentially meet Palau's biodiversity goals. As there are also complex and important resource-use and cultural issues to be considered in the selection and management of protected areas, an interactive process of weighing conservation priorities against a wide range of other resource-management priorities is required to develop a Protected Areas Network design that best meets Palau's objectives.

Much of the ownership and control of natural resources in Palau operates at the State level[1]. However, many of the natural resources and biodiversity span the whole of Palau. In order to best consider all of Palau's biodiversity and natural resource issues, it was viewed that a nationwide Protected Areas Network perspective would be required, recognizing that any final decisions would be subject to extensive discussion and negotiation at the State level.

The development of this national level perspective has been iterative. A first iteration was completed, but was viewed as inadequate due to limited data. This first iteration, however, enabled the effective identification of key data gaps which were subsequently filled. With improved spatial data it has been possible to complete a second more comprehensive iteration that provides the primary basis for this report.

First Iteration: SPOT Analysis

Forty-one conservation targets were initially selected at an expert workshop in Palau in 2002 (see Table 1). Because of a lack of spatial data for many of these targets, only twenty-four targets were used in the first iteration analysis (targets marked with an asterisk - Table 1).

[1] This is effectively the community level as the States are small, most including only several villages or hamlets

Table 1. First Iteration Conservation Targets

Coral Reefs
1. Barrier reefs *
2. Channels through barrier reefs *
3. Lagoon patch reefs *
4. Outer fringing reefs *
5. Island Fringing reefs *
6. Fringing reefs *
7. Sunken barrier reefs
8. Offshore banks and reefs
9. Atolls

Seagrass
10. Shallow seagrass beds
11. Deep seagrass beds

Marine water resources
12. Estuaries
13. Stratified Marine Lakes (meromictic) *
14. Vertically-Mixed Lakes (holomictic) *

Lagoon and sediment bottoms
15. Deep lagoon areas
16. Halimeda meadows

Beaches
17. Beaches (littoral zone)
18. Rocky shores

Mangroves
19. Coastal and Riverine Mangroves *
20. Marine Lake mangroves

Forest / vegetation
21. Volcanic soil forest, * (split into mature, secondary and degraded classes)
22. Riverine forest
23. Swamp forest *
24. Atoll forest
25. Rock Island Forest *
26. Limestone Forest (Anguar, Peleliu) *
27. Strand vegetation
28. Savanna / grasslands *

Fresh water resources
29. Streams
30. Lakes *
31. Freshwater marsh *

Other Special Targets

Fish Spawning Aggregations
32. Transient fish spawning aggregation sites *
33. Resident fish spawning sites

Other nesting sites
34. Turtle nesting beaches and cays *
35. Green Turtle feeding areas *
36. Hawksbill Turtles feeding areas *
37. Dugong concentration areas *
38. Crocodile nesting areas / corridors
39. Micronesian megapode nesting areas
40. Fruit Bat roosting areas
41. Nesting cliffs and caves

The Spatial Portfolio Optimization Tool (SPOT)[2] was used to analyze these data and produce portfolios of important biodiversity areas for a number of different scenarios. The scenarios ranged from selection of areas already included in existing protected areas through to unconstrained selection of areas by SPOT. Other scenarios examined the impacts of locking-in areas such as those recommended by previous rapid ecological assessment work in Palau and impacts of including all upper watershed areas in protected areas. This work is reported separately in Hinchley and Sheppard (2004).

The results of this first iteration analysis showed that there was likely to be ample scope for meeting biodiversity conservation goals under a variety of different scenarios, based on mapping of biodiversity targets to date. However, it was also recognized that more work was needed to improve the quality of some of the data and to complete the mapping of the missing targets.

This work was presented to Palau Tropical Moist Forest Ecoregion the TNC/WWF/NCC Eco-regional Assessment Peer Review Workshop in November 2005 for feedback and review. Following a positive response and support for the approach being used, it was recommended that work continue to improve the spatial data for analysis and that a second iteration of the analysis be conducted incorporating the new data sets.

[2] The Spatial Portfolio Optimization Tool (SPOT) is a generalized tool for conservation portfolio selection, using a flexible approach to design an efficient portfolio around specific conservation goals (Shoutis 2003). It analyzes a region by dividing it into small parcels called analysis units, then forms a portfolio by marking individual units as included or excluded from a portfolio. Using a process known as simulated annealing (a general technique for finding the lowest value of a function through many trial runs and repeated adjustment to input values). SPOT forms and analyzes millions of portfolios while searching for the most efficient portfolio. Each is evaluated according to three criteria: (1) How well it meets conservation goals; (2) the area included; and (3) the level of fragmentation of the portfolio. The portfolio that does the best job of minimizing the area and fragmentation while meeting conservation goals is considered the most optimal and is output as the result, that is, a scenario.

Second Iteration: MARXAN Analysis

Two expert workshops were held in May 2006 to: (1) develop an agreed set of protected area design principles, stratification, conservation targets and goals and (2) to provide a range of PAN scenarios for review by workshop participants. The workshop was attended by representatives of the main science and resource management agencies in Palau as well as representatives from States and the National Government. The first workshop focused on expert and stakeholder review and refinement of available biodiversity and socio-economic spatial information. The design principles for guiding decisions about the most suitable areas for inclusion in a protected areas network were also discussed and a working group was tasked with reviewing and refining these. Information obtained in the first workshop was digitized and compiled for analysis using MARXAN[3], a conservation planning tool developed to aid in the design of reserve options. During the second workshop several scenarios were presented and discussed. The future role for using spatial data and MARXAN to examine scenarios that could assist with development of the protected areas network was also discussed.

The key objectives of **Workshop 1** were to develop:

1. **PAN Design Principles** - the overarching guidelines or criteria describing important design principles for Palau's Protected Areas network.
2. **Stratification** - a map of how we need to divide the planning area to represent the full range of environmental and geographic variation that exists within the study area.
3. **Conservation Targets** - the spatial distribution (GIS maps) of the major biodiversity features under consideration
4. **Conservation Goals** - initial estimates of how much of each target should be protected/managed for long-term sustainability of the conservation targets being considered
5. **Data for Cost Surface** - those factors likely to have positive or negative impact on the PAN (also mapped in GIS)

The key objectives of **Workshop 2** were to:

6. Review the PAN scenarios generated from the parameters developed in Workshop 1
7. Provide feedback on scenarios and discussion of possible uses of MARXAN analysis to help identify areas that could be included in the nationwide network of protected areas in Palau
8. Identify information gaps and future research and data needs.

DESIGN PRINCIPLES

The workshop split into three working groups to develop design principles for the PAN. The Draft design principles for Kimbe Bay, PNG, were used as a starting point for discussion for the marine working group. Draft terrestrial principles developed by Sean Austin were used as a starting point for the terrestrial discussion. A third group discussed socio-economic principles that need to be considered in developing the PAN (also using draft principles from Kimbe Bay as an example). Following the workshop a small group[4] combined the principles into a single set of draft principles. Where possible and practical, the design principles were considered in the analyses. The draft principles developed for the Palau PAN are shown in Appendix 1.

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[3] MARXAN (Marine Reserve Design using Spatially Explicit Annealing) was developed by Ian Ball and Hugh Possingham of the University of Queensland to aid in the design of the Great Barrier Reef Marine Park. For a full description of MARXAN see Ian Ball and Hugh Possingham (2000) – MARXAN (v1.8.2) Marine Reserve Design using Spatially Explicit Annealing – A Manual prepared for the Great Barrier Reef Marine Park Authority. This manual is available on the University of Queensland MARXAN website.

[4] Andy Bauman, Vernice Stefano, and Alan Olsen

STUDY AREAS, STRATIFICATION AND PLANNING UNITS

Planning units provide the individual unit of choice for selection. We generated a planning unit layer that consisted of 20,762 - 15 ha hexagons across the entire study area. The 15ha size chosen provides a fine enough scale to allow the development of refined areas while simultaneously keeping the number of planning units constrained to a number where the processing time in MARXAN was manageable. The stratification provides the overarching template within which each goal would be sought. This ensures that representation, geographic spread and replication (our design principles) are effectively incorporated in the analyses.

Stratification units are used within MARXAN to ensure the sampling of the full range of environmental and geographic space when meeting conservation goals. It also ensures that representation goals are met in accordance with the design principles. Stratification forces MARXAN to select planning units from each stratum when meeting conservation goals. The stratification units therefore need to define meaningful and different ecological units across Palau. For example, environmental conditions on fringing reefs on the east side of Babeldaob are likely to be different to those on the more protected western side.

Participants in Workshop 1, reviewed the landscape/seascape stratification developed during the first iteration SPOT Analysis (see Figure 2). The group was of the opinion that the existing stratification did not reflect the full scope of environmental and geographic variation evident across Palau. The stratification was revised to separate the northern lagoon areas from the reef and lagoon systems to the east and west of Babeldaob. The southwest islands were also placed in a separate stratification unit. The final stratification is shown in Figure 1.

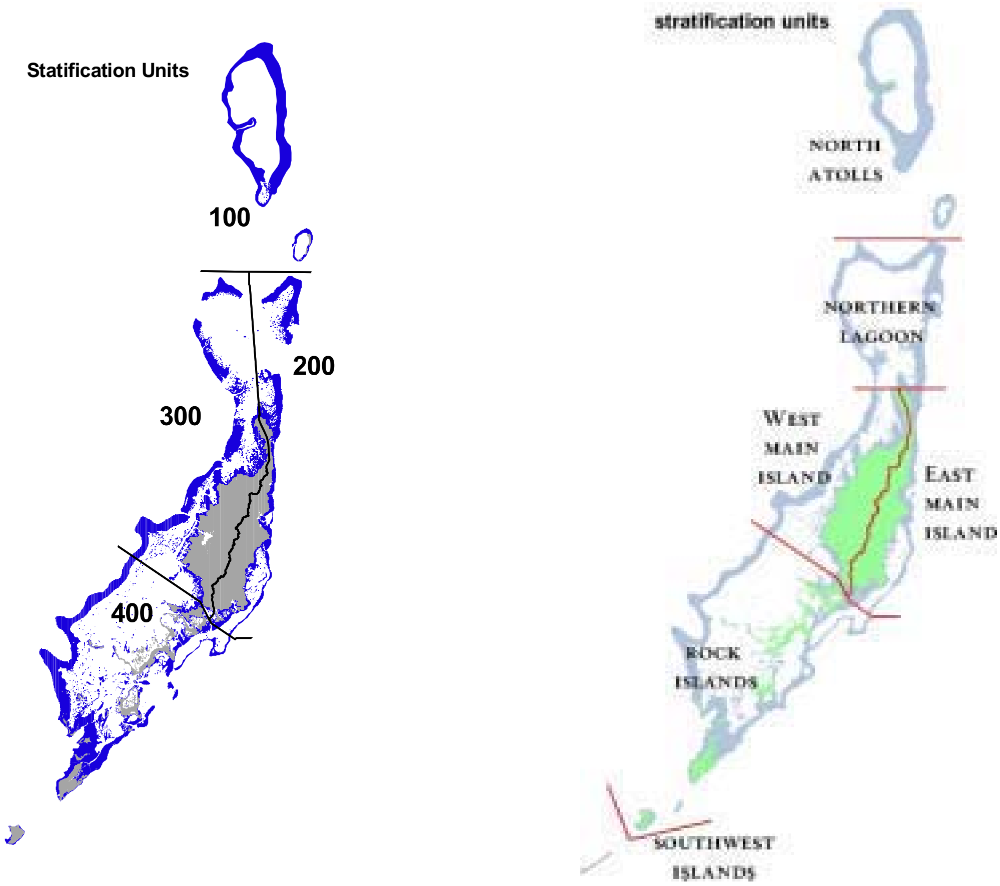


Figure 1. Stratification - Proposed - First Iteration (left); Revised - Second Iteration (right)

CONSERVATION TARGETS

The best available data were gathered from all sources, including PALARIS (Palau Automated Land and Resources Information System), local experts and published literature. Prior to the expert workshops, all spatial data was compiled and produced as maps for review by the experts. The starting point for spatial data was the list of "biodiversity targets" (e.g., ecosystems, habitats, species and special areas such as turtle nesting or spawning aggregation areas) developed in an expert workshop held during the first iteration in 2002. Data collection and mapping work since then (mainly by TNC, PALARIS, PICRC and PCS) has resulted in significant improvements to both existing data sets and the development of new spatial data sets, and the revised datasets were provided to Workshop 1 (see Table 2).

A total of 44 conservation targets were identified during the second iteration. These consisted of 34 coarse filter targets and 10 fine filter targets and/or assemblages derived from expert opinion and published literature (see Table 2). Data was unavailable at the time of analysis for #17 and #18 (Algal Beds and Sea Grasses). In addition it was not possible to derive #34 and #43 (Rocky Shores and Nesting Cliffs and Caves) in the time between workshop 1 and 2. Finally, #30, the streams target was viewed as effectively captured within the buffers of the Riverine Forest and Swamp Forest Targets (#23 and #24) (see Table 2). A total of 39 targets were used in the analysis, a significant improvement on the 24 targets used in the first iteration (see Table 2). Of these, 16 were marine or coastal systems, 10 were terrestrial systems, 3 were freshwater aquatic, 4 were aggregation areas of multiple species, 5 were focal areas for individual species (hawksbill turtle, green turtle, dugong, saltwater crocodile, fruit bat) and one was a coastline feature. For a complete description of each target see Appendix 2 and 3.

Unfortunately, data on the distribution of many of Palau's rare, threatened and endemic species is scant, inconsistent or unverified. The IUCN Redlist provides the details on the current listing of threatened species for Palau (see Appendix 6). The total number of listed species in Palau includes:

- Terrestrial - 1 extinct terrestrial species, 17 listed species and 46 species for which insufficient data is available (see below)
- Marine – 32 listed species and 14 species for which insufficient data is available.

We assumed for this assessment that most threatened species were captured within coarse filter targets, although this needs to be tested.

Coarse filter targets or systems targets are defined as dynamic spatial assemblages of ecological communities that: 1) occur together on the landscape, 2) are tied together by similar ecological process, underlying environmental features, or environmental gradients, and 3) form a robust, cohesive, and distinguishable unit (Groves et al. 2000). Broad marine and terrestrial systems targets were derived using satellite imagery and were available for coral reefs and forests. Coral reef system targets were originally mapped from USGS 1:25,000 topographic maps by PALARIS. The IMARs classification (derived from Landsat 7) data was further used to update these polygons. Forest/vegetation systems targets were based on a vegetation classification derived from 2003 Landsat 7 imagery (Boucher 2003). This classification was further modified to include riverine and swamp forest types. Riverine forests were derived using a 10m buffer on the existing streams data layer. Swamp forests were derived by selecting for forest areas occurring on swamp soil types. The systems targets were accepted at the expert workshop as the best available representation of that suite of targets and were not modified by the experts.

Other special targets were primarily species and species assemblage targets (see Table 2). These were reviewed and refined in Workshop 1. The workshop was divided into Marine, Socio-economic and Terrestrial working groups, whose members with relevant expertise assessed each data layer. Each data layer stimulated considerable discussion and debate and polygons were refined and modified to define the best "expert" representation of the spatial extent of the target under consideration. Small maps of each target layer are included in Appendix 7 together with details of the sources of data (Appendix 2) and descriptions (Appendix 3).

Table 2. Second Iteration Conservation Targets

	Coral Reefs		
1	Barrier Reefs	23	Riverine Forest
2	Channels through Barrier Reefs	24	Swamp Forest
3	Other Reef Channels	25	Atoll Forest
4	Lagoon Patch Reefs	26	Limestone Forest - Rock Islands
5	Outer Fringing Reefs	27	Limestone Forest – Other Islands
6	Island Fringing reefs	28	Savanna / Grasslands
7	Sunken Barrier reefs	29	Scrub Savanna
8	Offshore Banks and Reefs		**Fresh Water Resources**
9	Atolls	30	Streams†
10	Sunken Atoll	31	Lakes - freshwater
	Marine Water Resources	32	Freshwater Marsh
11	Estuaries	33	Other Freshwater Pools
12	Stratified Marine Lakes (meromictic)		**Other Special Targets**
13	Vertically-Mixed Lakes (holomictic)	34	Rocky Shores*
	Lagoon and sediment Bottoms	35	Fish Aggregation Sites (Transient)
15	Deep lagoon areas	36	Fish Aggregation Sites (Resident)
16	Lagoon Terrace	37	Turtle Nesting Beaches and Cays
17	Algal Beds*	38	Other Beaches
18	Sea Grasses*	39	Turtle Feeding Areas
	Mangroves	40	Dugong Feeding or Concentration Areas
19	Coastal and Riverine Mangroves	41	Important Bird Areas
	Forest/Vegetation	42	Fruit Bat roosting areas
20	Volcanic Soil Forest, (Mature A)	43	Nesting Cliffs and Caves*
21	Volcanic Soil Forest, (Secondary B)	44	Crocodile Critical Habitat
22	Volcanic Soil Forest, (Degraded C)	45	Important Insect Areas

* Data was not available at the time of analysis, or it was not possible to derive the target in the time available between workshop 1 and 2, therefore these targets were not included in the assessment
† Targets for streams were viewed as effectively captured within Riverine Forest and Swamp Forest

VIABILITY ASSESSMENT

Unlike many landscapes and seascapes which have been substantially altered by human activities, Palau and its landscapes and seascapes are still relatively intact. What this means from a protected areas network design standpoint is that there are a great many more options available when developing a protected areas network. What it also means is that most, if not all ecosystems are inherently viable because they are largely intact. Measures of viability according to the TNC guidelines require an assessment of size, condition and landscape context. While this approach is appropriate for terrestrial systems, our understanding of these notions with respect to marine systems is in its infancy. Rather than speculate about the relative viability of targets, we have chosen to assume that all of our targets are viable at the present time.

Size (BLM)

The Boundary Length Modifier (BLM) within MARXAN determines the relative clustering or scattering of "areas" depending on the setting used. A clumped scenario tends to form larger areas that meet many conservation goals, while a scattered scenario tends to form many smaller areas that often meet fewer goals in any given clump, but results in smaller overall area to meet all conservation goals. The broad conservation goals (e.g. 40% of Barrier reefs per stratum) and design principles (e.g. at least three replicates per stratum) provide the fundamental constraints within which MARXAN seeks to develop optimal solutions. The Boundary Length Modifier is then adjusted using test scenarios to find a setting that best meets these constraints. This also means that the goals and design principles to some extent pre-define the minimum size. A preliminary analysis of size as a determinant of viability is shown in Table 3. These ball park estimates are based on consultation with experts, evaluation of the historic extent of the system targets, and review of published literature (including other ecoregional plans). We set minimum size criteria to guide selection of areas of sufficient size to sustain the systems, as well as the nested species targets within them. Whether the sizes of these areas are "sufficient" will be determined by monitoring the protected and managed areas established as part of the PAN.

Landscape context (BLM and cost surface)

The landscape context for PAN involves the complex interplay between meeting the conservation goals for multiple targets, preferentially selecting those areas that are favourable for conservation and avoiding those that are unfavourable for conservation, all within the constraints of the predefined clumping parameters defined above. Because Palau is relatively intact, the opportunities for appropriate connectivity and interchange for both terrestrial and marine systems is high and the landscape context for most values would be defined as good to very good. This again supports the notion of the inherent viability of all existing values. The cost surface layer ensured that selection of areas to meet biodiversity goals was weighted against inclusion of areas negatively influenced by existing or proposed developments that would reduce their long-term viability of a given site.

Condition (Conservation goals (weightings) and cost surface)

Condition was considered from the standpoint of the relative influence (both positive and negative) of extrinsic factors on the long term ecological integrity of a given site, where a site might consist of one or more targets. Condition was considered in MARXAN using the costs surface as detailed in Figure 3. Threatening processes or areas where threatening processes were more likely are defined in the right column (negative factors). Because MARXAN preferentially selects the least threatened sites, the condition of the areas within which MARXAN selects is good to very good, which again means that the targets retained in the areas identified are likely to be viable. For example, preferential selection of sites with a low bleaching risk (high resilience), are likely to be in a better condition than high bleaching risk. Similarly, mature forests will be preferable to the degraded forest types.

From a terrestrial standpoint the most appropriate way to develop a protected area system that is viable is to determine those species that are most space limited or most vulnerable to fragmentation and to design the protected area system using the parameters that enable these species to persist in the landscape (i.e. the Focal Species approach – Lambeck 1997). At the present time, these data are unavailable and we would recommend that a Focal Species approach is developed to ensure that the space demanding threatened fauna are effectively considered.

To further address the issue of viability, scenario maps will be reviewed to eliminate areas from consideration because of size, poor condition and/or poor landscape context. This will be done during the consultation and review stage with local communities and experts to determine actual protected areas on the ground.

Table 3. Minimum patch size of targets

Local (1 acre or less)	Intermediate (30+ acres)	Coarse (500+ acres)
Terrestrial/freshwater targets		
Swamp Forest	Scrub Savanna	Mature volcanic forest
Rock Island Limestone Forest	Savanna / Grasslands	Secondary volcanic forest
Secondary limestone forest	Costal and Riverine Mangrove Forest	Degraded volcanic forest
Caves/Limestone Cliffs	Riverine forest	
Atoll forest		
Freshwater lakes		
Freshwater swamps		
Marine targets		
Local (1 acre or less)	**Intermediate (30+ acres)**	**Coarse (500+ acres)**
Island fringing reefs	Outer fringing reefs	Barrier reef
Lagoon patch reefs	Island fringing reefs	
Channels through barrier reefs	Sunken barrier reefs	
Stratified marine lakes	Offshore banks and reefs	
Vertically mixed marine lakes	Sunken atolls	
Atolls		
Other targets		
Spawning aggregation sites	Dugong feeding areas	
Saltwater croc (critical habitats)	Turtle feeding areas	
Turtle nesting beaches and cays	Important bird areas	
Other beaches	Important insect areas	
Fruit bat roosting areas		
Nesting cliffs and caves		

THREATS

Table 4 below provides an overview of the major threats to the identified conservation targets. These threats were identified through expert workshops as part of the Conservation Area Planning process conducted in Palau. Brief descriptions of the threats are also provided in Appendix 4.

More detailed analysis of the source, severity and scope of the threats outlined above have been carried out through a number of Conservation Action Planning (CAP) exercises in Palau, including:

1. CAP planning with Koror State for the Rock Islands Southern Lagoon Area as a component of work leading to the development of a comprehensive Management Plan for the area over the period 2003-2005. Some of this work was carried out in conjunction with a series of peer review workshops (Marine Efroymson Workshops) (Smith et al. 2002).

2. A series of Efroymson workshops during 2004-2005 to undertake CAP for the main island of Babeldoab, in partnership with Palau Conservation Society, with review by peers undertaking similar planning work in Yap, Kosrae, Pohnpei and PNG (Sengebau et al. 2004), and

3. CAP workshops with Palau Conservation Society for the Northern Lagoon Area during 2006.

Together these CAP exercises provide a detailed examination of the threats to conservation targets in Palau's marine, terrestrial and freshwater ecosystems and have been used in developing and implementing strategies to meet conservation goals and deal with the threats.

Table 4. Threats to Conservation Targets

	Barrier Reefs	Cannels through barrier reefs	Other reef channels	Lagoon Patch Reefs	Outer Fringing Reefs	Island Fringing Reefs	Sunken barrier reefs	Offshore banks and reefs	Atolls	Estuaries	Marine Lakes (stratified)	Marine Lakes (vertically-mixed)	Deep lagoon areas	Lagoon terrace
STRESSES														
Habitat loss	L				L	L								
Habitat fragmentation					L	L								
Changing species mix / population-age structure	H	H	M	H	H	H	M	M	L				M	M
Decline in habitat quality or condition (water quality, sedimentation)	L	L	M	M	H	H				L				
Decline in habitat quality or condition (habitat structure)	L	L	L		L	L								
Introduction of non-native species.		L	L						L	L	M	M		
SOURCES OF STRESS														
Overharvesting - fishing, hunting of native animal species	H	H	M	H	H	H	L	L	H	L			M	H
Overharvesting - native plants														
Destructive harvesting practices	M	L	L	M	M	M								
Land clearing (roads, development, infrastructure, agriculture)				L	M	H			L	L				
Wildfires														
Quarrying / mining														
Dredging				L	H	H								
Land filling/reclamation														
Ship groundings	H	H	M	L	M	M			L					
Invasive Animals											M	M		
Invasive Plants											L	L		
Pesticide and fertilizer misuse														
Solid waste disposal / littering										L				
Water Pollution (sewage, oil spills, urban runoff)	L			L	M	M				L	L	L		
Tourism activities	M			L	L	L			L		M	M		
Climate change (likely longer term source of stress)	H	M	M	H	H	H	M	M	H	H	H	H	L	L

	Algal beds	Seagrass beds	Castal and Riverine Mangroves	Volcanic Soil Forest (Mature)	Volcanic Soil Forest (Secondary)	Volcanic Soil Forest (Degraded)	Riverine Forest	Swamp forest	Atoll Forest	Linestone forest - Rock islands	Limestone forest - other islands	Savanna / Grasslands	Scrub savanna	Streams
STRESSES														
Habitat loss	L	L	H	M	M	M	M	M	M	L	M	M	M	L
Habitat fragmentation		L	M	H	H	H	M	L	M	L	H	L	L	
Changing species mix / population-age structure			L	L	L	M	L	L	L					L
Decline in habitat quality or condition (water quality, sedimentation)		M	M				L	M						H
Decline in habitat quality or condition (habitat structure)			M	L			L	M				L	M	
Introduction of non-native species.			L	M	M	M	M	H	H	H	H	H	H	M
SOURCES OF STRESS														
Overharvesting - fishing, hunting of native animal species	M	M	M	M	M	M	L	L	M	M	M			
Overharvesting - native plants			L	M	M	M	M	M	L	L	L			
Destructive harvesting practices			L											
Land clearing (roads, development, infrastructure, agriculture)	L	L	H	H	H	H	H	H	L	L	M	H	H	H
Wildfires				H	H	H	L	L	L	L	M	H	H	M
Quarrying / mining				M	M	M	M	M		M	L			H
Dredging		M												
Land filling/reclamation			H					M						H
Ship groundings														
Invasive Animals				M	M	M	M	M	M	M	H	L	L	M
Invasive Plants				H	H	H	H	H	M	H	H	H	H	M
Pesticide and fertilizer misuse			M											M
Solid waste disposal / littering											L			H
Water Pollution (sewage, oil spills, urban runoff)		H												H
Tourism activities		L								M				
Climate change (likely longer term source of stress)			H	H	H	H	H	H	H	H	H	M	M	L

	Freshwater Lakes	Freshwater Marsh	Other freshwater pools	Rocky shores	Fish aggregation sites	Turtle nesting beaches	Other Beaches	Turtle feeding areas	Dogong areas	Important Bird Areas	Fruit bat roosting areas	Crocodile critical habitat	Important Insect Areas	*No. targets with HIGH ranking*	*No. targets with MEDIUM ranking*	*No. targets with LOW ranking*	*Total targets affected*
STRESSES																	
Habitat loss		M	M			L	L	L	L	H	H	L	L	*3*	*11*	*13*	*27*
Habitat fragmentation												L	L	*4*	*3*	*9*	*16*
Changing species mix / population-age structure	L				H			H	H	H	H	L	L	*10*	*6*	*11*	*27*
Decline in habitat quality or condition (water quality, sedimentation)	L	H	H		L			L	M					*5*	*6*	*7*	*18*
Decline in habitat quality or condition (habitat structure)					L	H	L							*1*	*3*	*10*	*14*
Introduction of non-native species.	L	H			L	H	M							*8*	*8*	*7*	*23*
SOURCES OF STRESS														*0*	*0*	*0*	*0*
Overharvesting - fishing, hunting of native animal species					H	H		H	M	H	H	L		*12*	*12*	*6*	*30*
Overharvesting - native plants										L				*0*	*5*	*5*	*10*
Destructive harvesting practices					M			M			M			*0*	*7*	*3*	*10*
Land clearing (roads, development, infrastructure, agriculture)		H	H	L		L	L		L	H	H	M	H	*15*	*3*	*11*	*29*
Wildfires	M													*5*	*3*	*4*	*12*
Quarrying / mining	L	M								L	L	L	L	*1*	*7*	*6*	*14*
Dredging					?				M					*2*	*2*	*1*	*5*
Land filling/reclamation												M		*2*	*2*	*0*	*4*
Ship groundings														*2*	*3*	*2*	*7*
Invasive Animals	M	M	M			H	L			M	L			*2*	*14*	*4*	*20*
Invasive Plants	L	H	H	L						M	L			*11*	*3*	*5*	*19*
Pesticide and fertilizer misuse		H	M											*1*	*3*	*0*	*4*
Solid waste disposal / littering		L	L			M	M							*1*	*2*	*4*	*7*
Water Pollution (sewage, oil spills, urban runoff)		L	L		L									*2*	*2*	*8*	*12*
Tourism activities	L				H	M	M			L				*1*	*6*	*7*	*14*
Climate change (likely longer term source of stress)	L				M	M				M	M	L	L	*17*	*10*	*6*	*33*

COST LAYER

The cost layer represents the relative influence (both positive and negative) of factors that are likely to affect the long-term ecological integrity of a protected area. A working group at Workshop 1 reviewed data layers considered relevant to the development of the cost surface and added new information as they thought necessary. Each factor was rated on a scale from -10 through to +10. Negative ratings represented factors considered likely to have a negative effect on a protected area (i.e. less suitable for inclusion), the more negative the number the less suitable the factor was considered to be. Positive ratings represent factors considered likely to have a positive effect on a protected areas (i.e. more suitable for inclusion), the higher the rating the more suitable the factor. A list of the data layers considered in the development of the cost surface and the ratings for each factor are shown below in Table 5. Small maps of these spatial data layers are shown in Appendix 8.

The cost layer was derived from the data layers and values defined in Table 5. Spatial data layers were assigned with their specific value (rating) and all values were summed for each planning unit to provide a total cost for each planning unit. The higher the cost, the less desirable that planning unit is for selection. For the cost layer, any cost input contributing ≥ 50% of a given planning unit was attributed that cost (e.g. If a layer with a cost of -5 contributed to 55% of that planning unit then the unit was considered as having a cost of -5. Conversely, if the layer contributed 45% then the value for that planning unit was set at 0. The final cost layer is detailed below in Figure 2.

Table 5. Socio-economic Factors and Ratings

No.	Name	Agreed Conservation Rating	No.	Name	Agreed Conservation Rating
Positive Factors			**Negative Factors**		
1	Existing Protected Areas	10	15	Near-shore Dredging	-10
2	Existing Protected Areas – large	8	16	Proposed Development	-9
3	Proposed Protected Areas	6	17	Existing aquaculture	-10
4	Traditionally Managed Areas	10	18	Proposed aquaculture	-9
5	Cultural / Historic sites	10	19	Mining Sites / Quarry	-10
6	Water Sources	9	20	Compact Road	-10
7	Upland Watersheds	5	21	Other Road	-5
8	Taro Patches	10	22	New Capital Site	-10
9	Dive Sites	10	23	Waste Disposal Sites	-10
10	Tourism Sites	5	24	Existing airports	-10
11	Higher survival after 1998 bleaching	10	25	Man-made features	-10
12	Better recovery since 1998 bleaching	10	26	Other existing developed areas	-10
13	Areas of known high coral diversity	10	27	Unsustainable farming	-7
14	Mangrove clam area	8	28	Invasive Species	-7

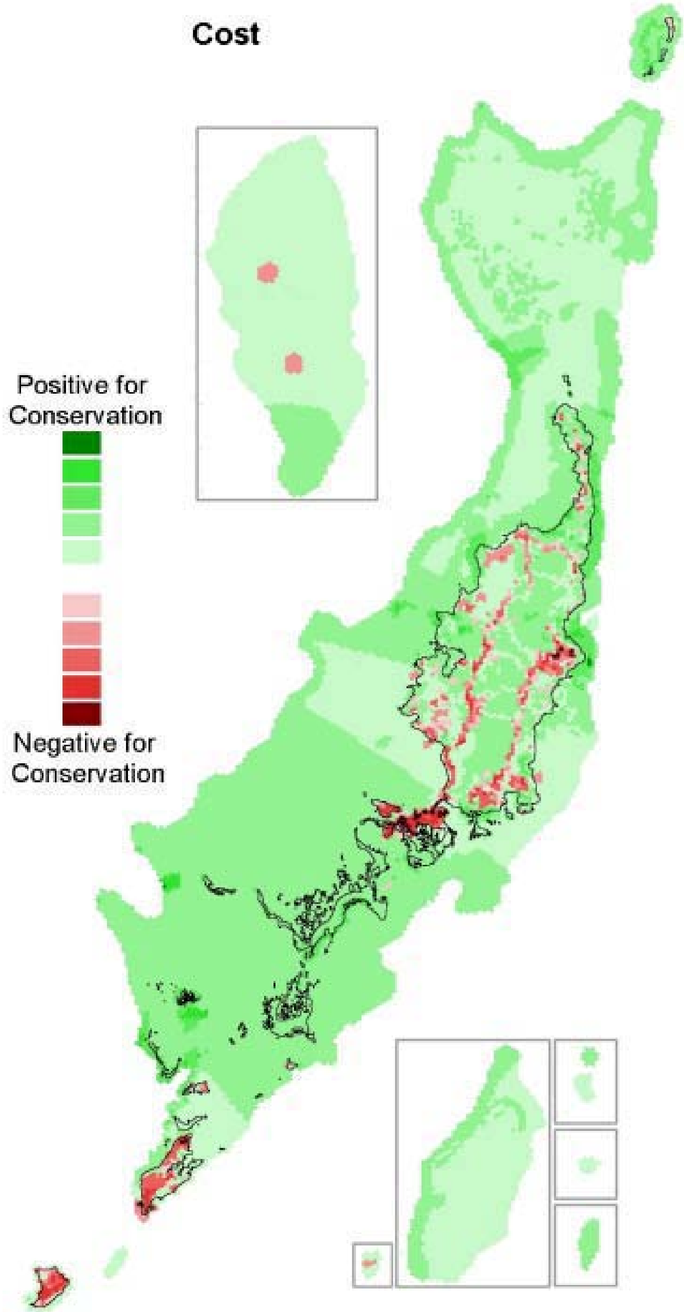


Figure 2. Cost Layer

CONSERVATION GOALS

Conservation goals are an expression of how much (e.g. area or number of viable occurrences) and spatial configuration of each conservation target is required to ensure the long-term viability of that target. The goals in this assessment represent an initial estimate of percentage goals necessary to maintain the biodiversity of Palau and contribute to the survival of species across their range. These goals should be considered as first approximations that will need to be reviewed and refined as more information becomes available.

To effectively capture all marine biodiversity, other planning efforts have suggested that 20% to 40% of habitats need to be conserved within protected areas (Beck and Odaya 2001, Ward et al. 1999). In general goals for widespread marine systems matched or exceeded those recommended for marine planning. The expert workshop took this precautionary approach based on our limited knowledge of many of the systems and species, the trend for increasing El Nino and bleaching events, and the very high diversity of fish and coral species found in Palau.

For terrestrial and coastal systems we considered geographic scale and spatial patterns and range-wide distribution patterns. As for the marine systems, many of the terrestrial systems are still almost completely intact so we were able to use the current distribution of the systems as the baseline to derive conservation goals. Because of the high endemicity and relatively small areas of terrestrial targets in Palau, and to ensure that endemic species were adequately addressed within each system, we used the precautionary principle and established relatively high goals for terrestrial and coastal systems.

The exceptions to this are the upland volcanic forest types (where clearing for agriculture and development has resulted in loss of up to 30% of the forest in some areas) and limestone forest of Angaur and Peliliu (which were severely damaged during World War II). For these systems, the *Vegetation Survey of the Republic of Palau* (Cole et al. 1987) based on 1976 aerial photography is useful as a baseline as it captured the vegetation at a point in time when it had sufficiently recovered from the impacts of World War II and a formerly much larger population (approximately 60,000 Japanese residents in 1940). At the time of the survey, forest and other natural vegetation covered approximately 90% of the land. To account for forest loss since this baseline we again used the precautionary principle and established relatively high goals for these forest types.

Intact freshwater aquatic systems in Palau are restricted to one of the five primary islands, Babeldoab. There has been minimal hydrologic modification to streams and lakes, therefore we utilized data compiled by the US Geological Survey (1984) as the base from which to derive goals. To capture these more restricted types, we established a goal of 50% of the historic extent of streams and 100% of freshwater lakes.

The initial goal estimates (V1 Goals) were reviewed by local experts at Workshop 1 to develop an agreed set of conservation goals for each of the conservation targets (V2 goals) as shown in Table 6 below. The marine and terrestrial working groups were provided with a draft set of goals that were developed during the first iteration of this ecoregional assessment work. These goals were reviewed and adjusted according to the discussions of the workshop participants. The V2 goals were used in this analysis.

Table 6. % Goals for each Biodiversity Target

Conservation Targets		V1 Goal	Agreed V2 Goal	Conservation Targets		V1 Goal	Agreed V2 Goal
1	Barrier Reefs	40%	**40%**	23	Riverine Forest	75%	**80%**
2	Channels through Barrier Reefs	60%	**60%**	24	Swamp Forest	75%	**90%**
3	Other Reef Channels	60%	**50%**	25	Atoll Forest	80%	**80%**
4	Lagoon Patch Reefs	40%	**40%**	26	Limestone Forest - Rock Islands	80%	**80%**
5	Outer Fringing Reefs	40%	**40%**	27	Limestone Forest – Other Islands	50%	**80%**
6	Island Fringing reefs	40%	**40%**	28	Savanna / Grasslands	30%	**30%**
7	Sunken Barrier reefs	40%	**40%**	29	Scrub Savanna	30%	**30%**
8	Offshore Banks and Reefs	40%	**40%**		**Fresh Water Resources**		
9	Atolls	40%	**40%**	30	Streams†	30%	**30%**
10	Sunken Atoll	40%	**40%**	31	Lakes – freshwater	100%	**100%**
	Marine Water Resources			32	Freshwater Marsh	50%	**50%**
11	Estuaries	50%	**50%**	33	Other Freshwater Pools		**50%**
12	Stratified Marine Lakes (meromictic)	100%	**100%**		**Other Special Targets**		
13	Vertically-Mixed Lakes (holomictic)	100%	**100%**	34	Rocky Shores*	30%	**30%**
	Lagoon and sediment Bottoms			35	Fish Aggregation Sites(Transient)	100%	**100%**
15	Deep lagoon areas	40%	**40%**	36	Fish Aggregation Sites(Resident)	100%	**100%**
16	Lagoon Terrace	40%	**40%**	37	Turtle Nesting Beaches and Cays	100%	**100%**
17	Algal Beds*		**40%**	38	Other Beaches		**30%**
18	Sea Grasses*		**40%**	39	Turtle Feeding Areas	50%	**40%**
	Mangroves			40	Dugong Feeding, Concentration Areas	50%	**50%**
19	Coastal and Riverine Mangroves	75%	**90%**	41	Important Bird Areas	80%	**80%**
	Forest/Vegetation			42	Fruit Bat roosting areas	75%	**75%**
20	Volcanic Soil Forest, (Mature A)	50%	**60%**	43	Nesting Cliffs and Caves	75%	**75%**
21	Volcanic Soil Forest, (Secondary B)	30%	**40%**	44	Crocodile Critical Habitat	75%	**40%**
22	Volcanic Soil Forest, (Degraded C)	20%	**20%**	45	Important Insect Areas		**50%**

* Data was not available at the time of analysis, or it was not possible to derive the target in the time available between workshop 1 and 2, therefore these targets were not included in the assessment
† Targets for streams were viewed as effectively captured within Riverine Forest and Swamp Forest

MARXAN ANALYSIS

Planning units are the fundamental unit of selection. Protected Areas planning requires the consideration and comparison of an enormous number of potential planning units. Protected areas design requires the selection of those planning units that satisfy a number of ecological, social and economic criteria (in this case our biodiversity targets, goals for each target layer, design principles and the effective consideration of the cost layer which incorporates socio-economic considerations). MARXAN is designed to help synthesise and automate the selection process so that many different scenarios can be developed and explored. One way of dealing with often conflicting biodiversity and socio-economic criteria is to have well defined goals for all of the conservation targets and well defined measures of the likely economic impact of the reserve system. The conservation goals are then sought in a way that the protected areas network results in minimal impact on community interests. The selection process uses an objective function whereby any collection of planning units is given a score. The simulated annealing procedure then attempts to find protected areas networks (i.e. collections of planning units) which have the lowest scores (socio-economic cost) and highest biodiversity benefit. This means that the scenarios produced try to meet the most conservation goals while simultaneously having the least impact on socio-economic values.

Key MARXAN Inputs:

The key inputs used in the MARXAN runs were:

- Total planning units = 20,762
- Each planning unit = 15 ha
- 10 runs where a run = 10,000,000 iterations
- Boundary Length Modifier = 0.7 (With testing between 0.01 - 1)
- Penalty Cost = 50 (Set equally across all conservation targets) which means all targets were weighted equally
- Temperature decreases 10,000
- Adaptive annealing “on”
- Using simulated annealing

For a complete description on the use of MARXAN see (Ball and Possingham 2000).

Data Management

All data used in this assessment is based on an agreed set of ArcView data layers outlined above in Tables 2 and 5. Copies of all GIS products and databases were retained at the Palau TNC Office, as well as deposited at the Indo-Pacific Resource Centre in Brisbane. Copies of all data layers and output layers have been made available to Palau’s national GIS data agency (PALARIS) to provide a central repository for use by partner agencies and organizations in Palau.

RESULTS

DESCRIPTION OF SCENARIOS

Scenarios were developed using MARXAN based on the targets, goals, stratification and cost layer information described above. Five scenarios were developed to provide a range of options for the consideration that would variously meet the conservation goals. These are described below, together with a summary of how well each scenario met the overall conservation goals for each target.

The map shown for each scenario shows the relative importance of areas for inclusion in protected areas network (Importance Rank - see Figure 3). Each scenario map represents the sum of 100 possible protected area network designs. The red areas represent those planning units which were present in 100 of 100 possible protected area network designs. These are the planning units for which there are few or no options available. That is, if we are to meet our conservation goals, then these planning units must be included in the protected area design. Conversely, the light green areas occur in less than 10 of 100 possible protected area network designs. These are planning units for which there are many options available to meet the conservation goals.

As a simple way to interpret the following scenarios, the red areas are most important for protection, that is, these areas are essential if we are to meet our conservation goals. These areas often contain conservation values that only occur in that area such as spawning aggregation sites. These areas also often meet multiple conservation values in a relatively small area.

The yellow and green areas are least important for protection, that is there is much greater flexibility to achieve our conservation goals. These areas often contain widespread conservation values such as fringing reefs where options for protection are enormous.

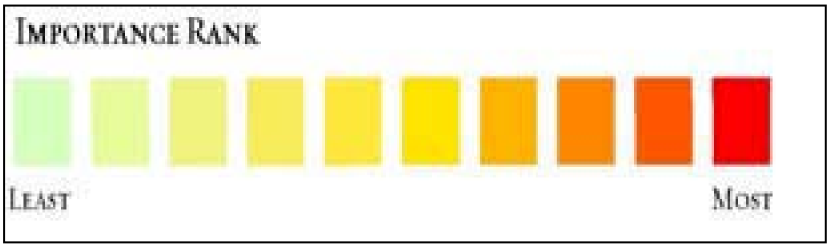
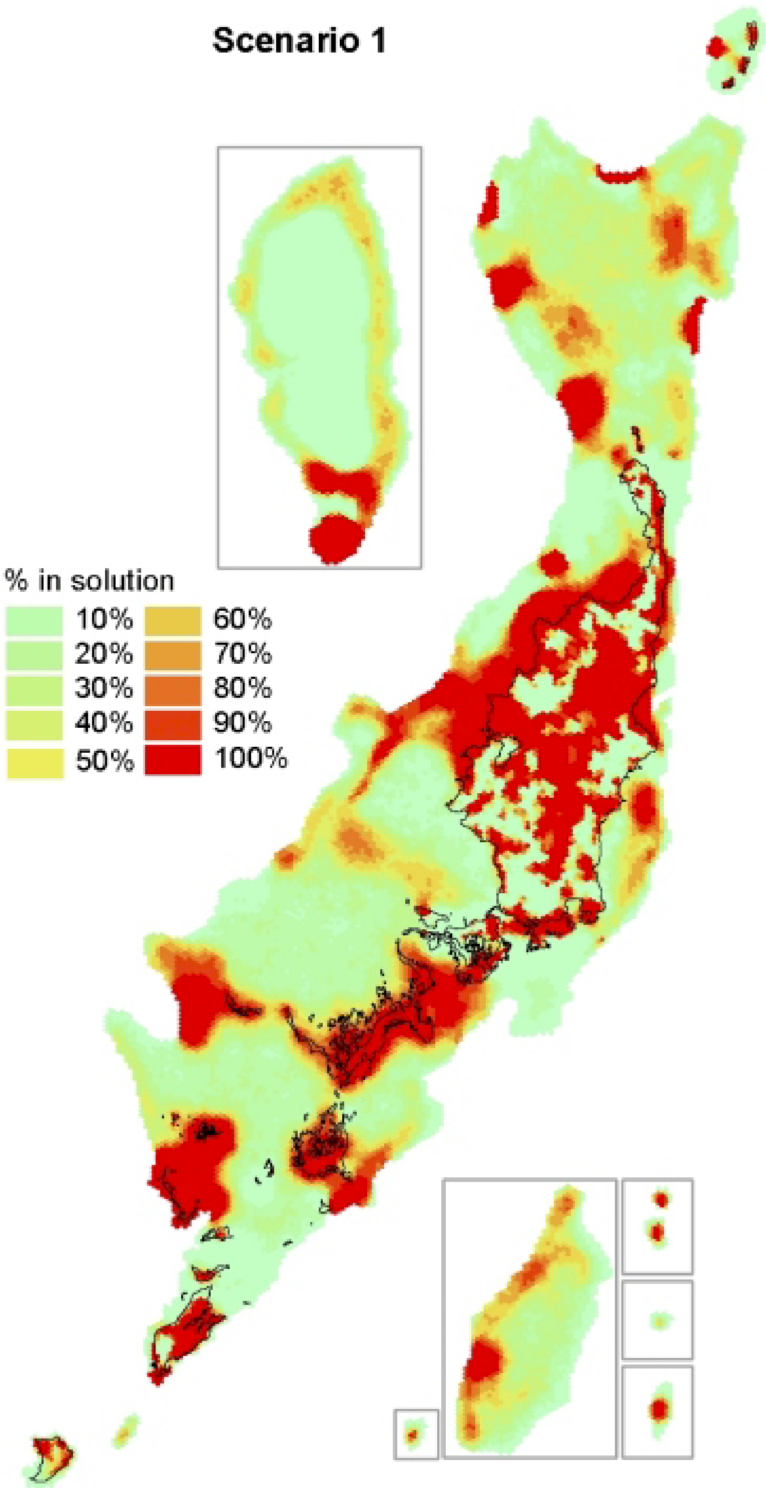


Figure 3. Importance Ranking Colour-Coding

Scenario 1. Unconstrained

This scenario allows MARXAN to search for areas to meet all conservation goals without including any existing or proposed protected areas.



This scenario was developed to show areas that best meet all conservation goals in the most efficient way. That is, it highlights the most important areas to achieve the conservation goals and the least important areas. MARXAN aims to meet the targets in the smallest area possible (within the constraints of the boundary conditions and cost layer) which forces MARXAN to clump planning units into contiguous areas as much as possible, rather than choosing scattered planning units. It doesn't automatically include existing protected areas, but can be used to compare with the existing protected areas and help plan possible additions to the network to better meet the conservation goals.

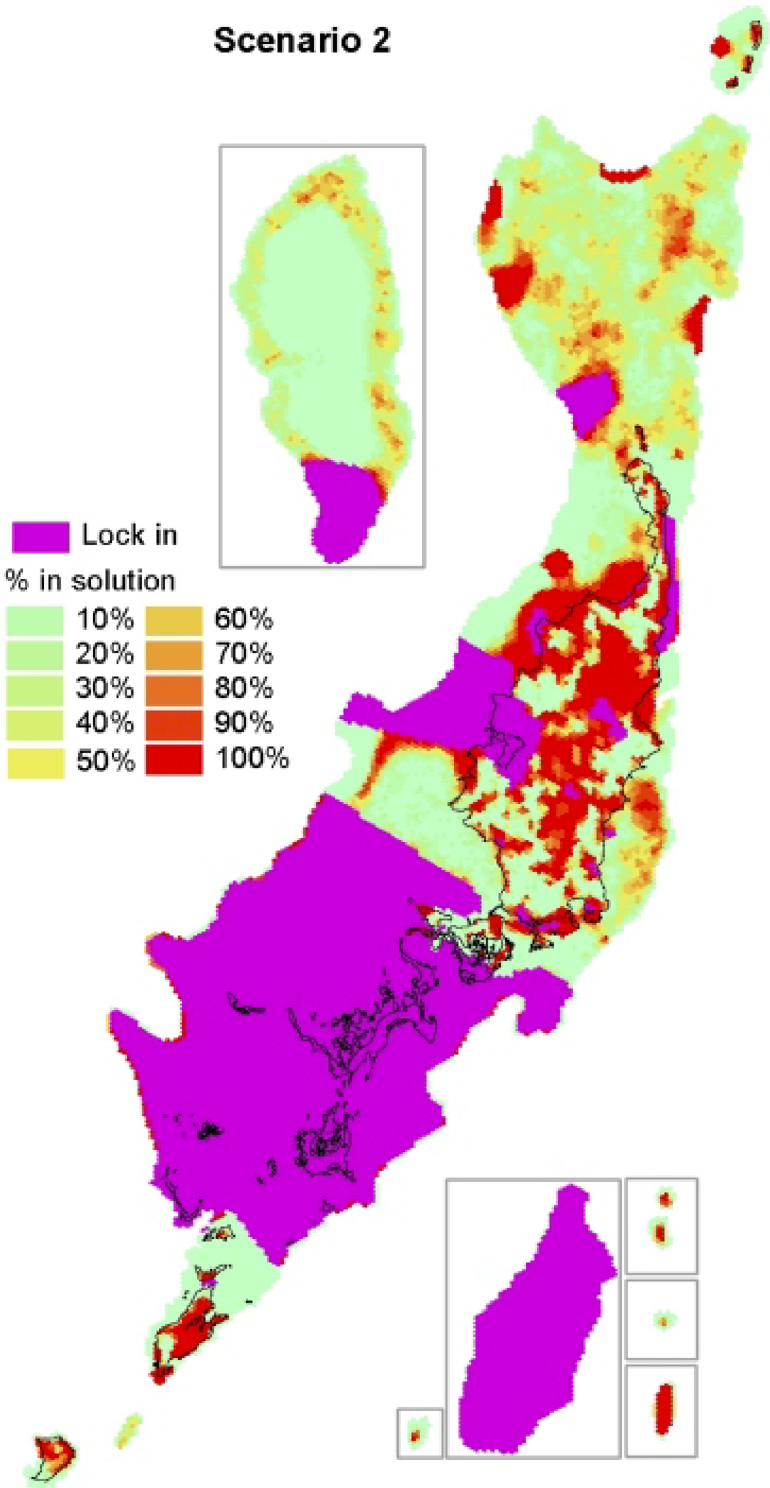
Because Palau's natural environment is still relatively intact, this scenario was able to meet or exceed all conservation goals for all of the conservation targets.

See Appendix 5 for details of the % goals met for this and other scenarios.

Figure 4. Scenario 1 - Unconstrained

Scenario 2. Existing Protected Areas

This scenario "locks in" all existing protected areas and then allows MARXAN to search for *additional areas* to fully meet conservation goals.



If all existing protected areas are included in the PAN, this scenario shows one example of additional areas that might also be protected or managed to conserve Palau's biodiversity. As for Scenario 1, all conservation goals were fully met in this scenario.

Slight differences in the new areas selected compared with Scenario 1 reflect the fact that many of the conservation goals are fully or partly met within existing protected areas (see Appendix 5).

Figure 5. Scenario 2 - Existing Protected Areas

Scenarios 3 and 4. Existing Protected Areas, Traditional Areas, Dive Areas & Proposed Protected Areas.

These two scenarios are quite similar. Scenario 3 "locks in" all existing protected areas and also traditional areas and dive sites and then allows MARXAN to search for *additional areas* to fully meet conservation goals. Scenario 4 is the same except that it also locks in proposed protected areas.

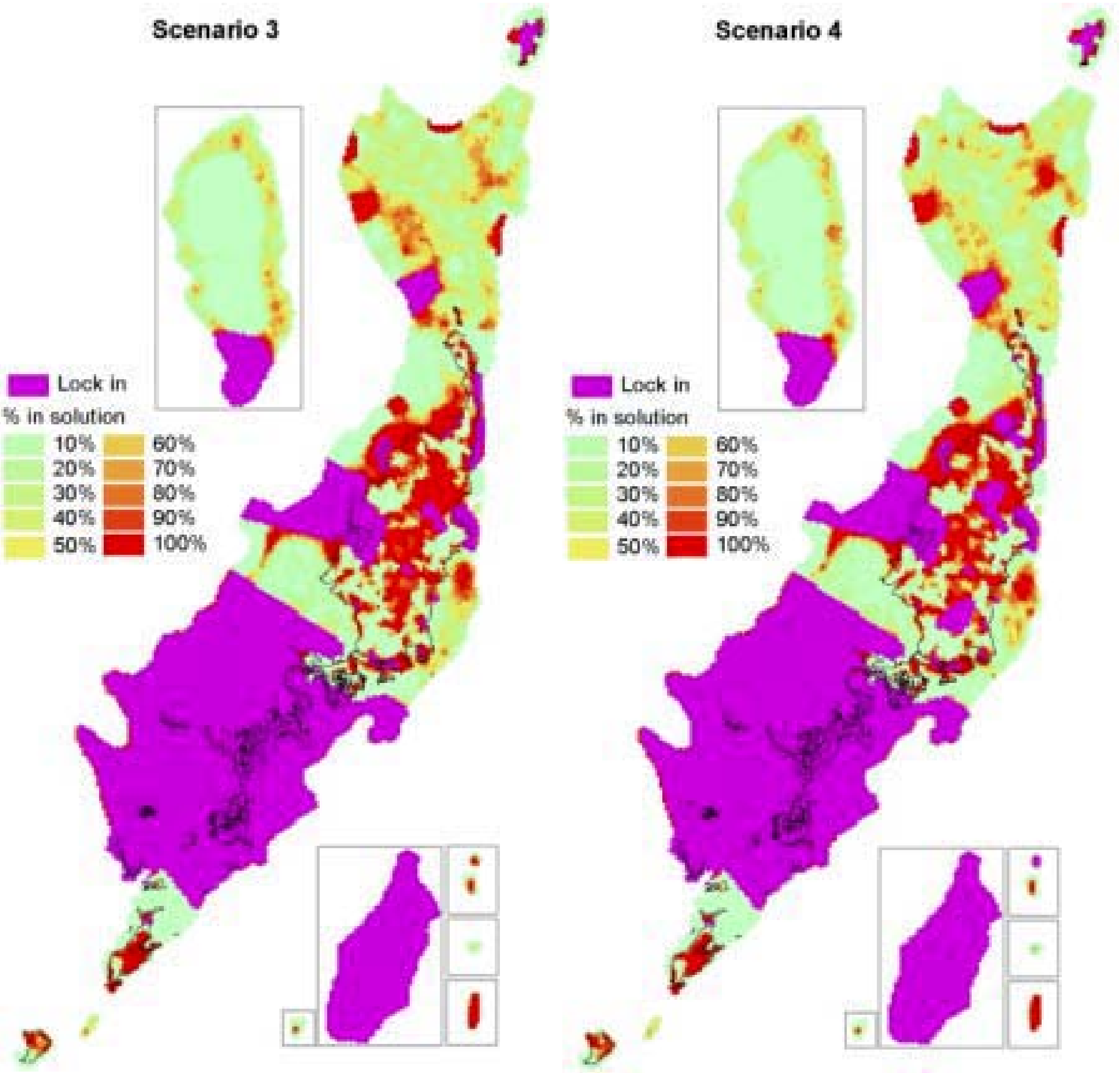


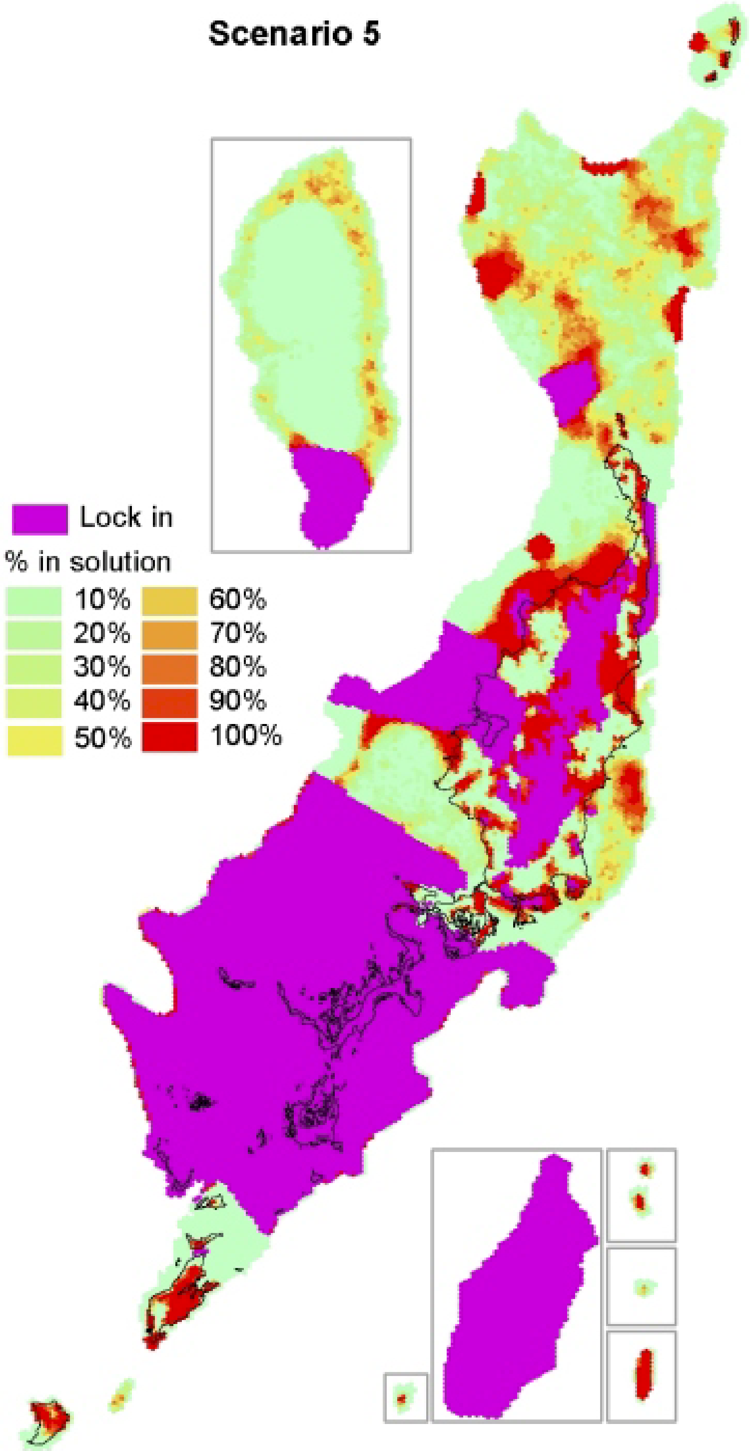
Figure 6. Scenario 3 -Existing Protected Areas, Traditional Areas, Dive Areas.

Figure 7. Scenario 4 -Existing Protected Areas, Traditional Areas, Dive Areas & Proposed Protected Areas.

These two scenarios both meet all conservation goals and produce very similar maps. The maps are also quite similar to the results of scenario 2, as the additional areas locked-in for these two scenarios are not large.

Scenario 5. Existing Protected Areas and Upland Watersheds.

Existing protected areas and the upland watershed areas on Babeldaob are "locked in" and then MARXAN searches for *additional areas* to fully meet conservation goals.



The upland areas of Babeldaob contain the largest contiguous areas of volcanic forest in Palau. As these areas run along the central ridge of Babeldaob, and are generally on steep slopes and constitute the upland areas of all the major watersheds, they have sometimes been proposed as high priority areas for protection. This scenario therefore examines the impact of locking-in all areas $\geq$ 225m above sea level along the central ridge.

Figure 8. Scenario 5 - Existing Protected Areas and Upland Watersheds

DISCUSSION

LOCAL EXPERT COMMENTS

The second expert workshop in Palau was used to obtain expert review of the scenarios and to examine the use of MARXAN and the scenarios as a tool to assist and guide the development of the PAN in Palau's political, social and cultural context.

The overall view from the workshop was that the areas defined in the MARXAN scenarios identified those areas that group viewed as important for protection and management. There was consensus that the national overview developed would need to be taken to each of the 16 States governments for their review and input. It was suggested that a finer scale analysis should be run for each State incorporating their values, views and priorities and that this should be where the national and State views should be harmonized.

There was recognition that the products from MARXAN and the language and interpretation of these products were crucial to the success or failure of this approach. Considerable thought needs to be given to the delivery, interpretation and explanation of MARXAN products for use in the States, or with other audiences, to avoid misinterpretation of the outputs from MARXAN – e.g. through misunderstanding limitations of the input data, or using the outputs as a "blueprint" rather than as providing a starting point for review and discussion.

It was also recognized that MARXAN could be used as a tool to periodically evaluate progress towards biodiversity and PAN goals at State and national levels.

Most concerns about the scenario outputs related to the development of the cost grid and related land management issues. For example there were some concerns about the large area identified as "protected areas" as these often encompass several different levels or types of management. Although some of these areas are protected under a management plan, the cost surface did not include delineation of the specific zonings and types of management within a protected area, that is, the delineation of "effectively managed areas" (e.g. The Rock Islands and Southern Lagoon Management Area is designated as one protected area, but within this there are zones with differing levels of protection). Also, traditionally managed areas were not fully included within the scenarios. There was recognition that many areas have already been managed traditionally through closed seasons or other means for hundreds of years and as yet these are not effectively captured in the existing data.

There were also concerns regarding the relative weightings within the costs surface and how that might influence the inclusion and or exclusion of sites. There was strong feeling that State/community information, data, values, priorities and concerns needed to be incorporated in the model on a State by State basis. There was also strong recognition of the need for capacity building in Palau, particularly with respect to building MARXAN capability and additional GIS support. This is particularly relevant if the PAN directorate decides to pursue a State by State evaluation.

INITIAL POLITICAL REVIEW

The results of the MARXAN Scenarios were presented before the Palau Congress (House of Delegates – State Representatives) 31 May, 2006. The results of the workshops and the MARXAN approach were well received and Delegates indicated they felt the results were extremely useful to guide and assist in the development of Palau's protected areas network. However, it was the view of the delegates that analyses would need to be developed at a finer scale at the State level to support the concerns and desires of each State. This supported the views expressed within the expert workshops.

GAP ANALYSIS

Scenario 2 locks-in existing protected areas prior to searching for additional areas to meet the conservation goals for each target. Analysis of the lock-in areas can be used to see how well conservation goals are currently being met within these areas. The results showed that the existing protected areas, if well managed, already fully meet several of the conservation goals (vertically mixed and stratified marine lakes, estuaries, atolls, sunken barrier reefs, channels through barrier reefs) and partly meet the remainder (see Figure 5 below). It also shows that a few of the targets (mainly the forest targets) are poorly represented in existing protected areas. See Appendix 5 for the full list of how well conservation goals are being met for each target within existing protected areas.

Scenarios 3, 4 and 5 show a similar gap analysis for existing protected areas plus other areas that could potentially be included in the protected areas network, that is, traditionally managed areas, dive sites, areas already proposed as protected areas, and the upland central ridge of Babeldaob (see Appendix 5).

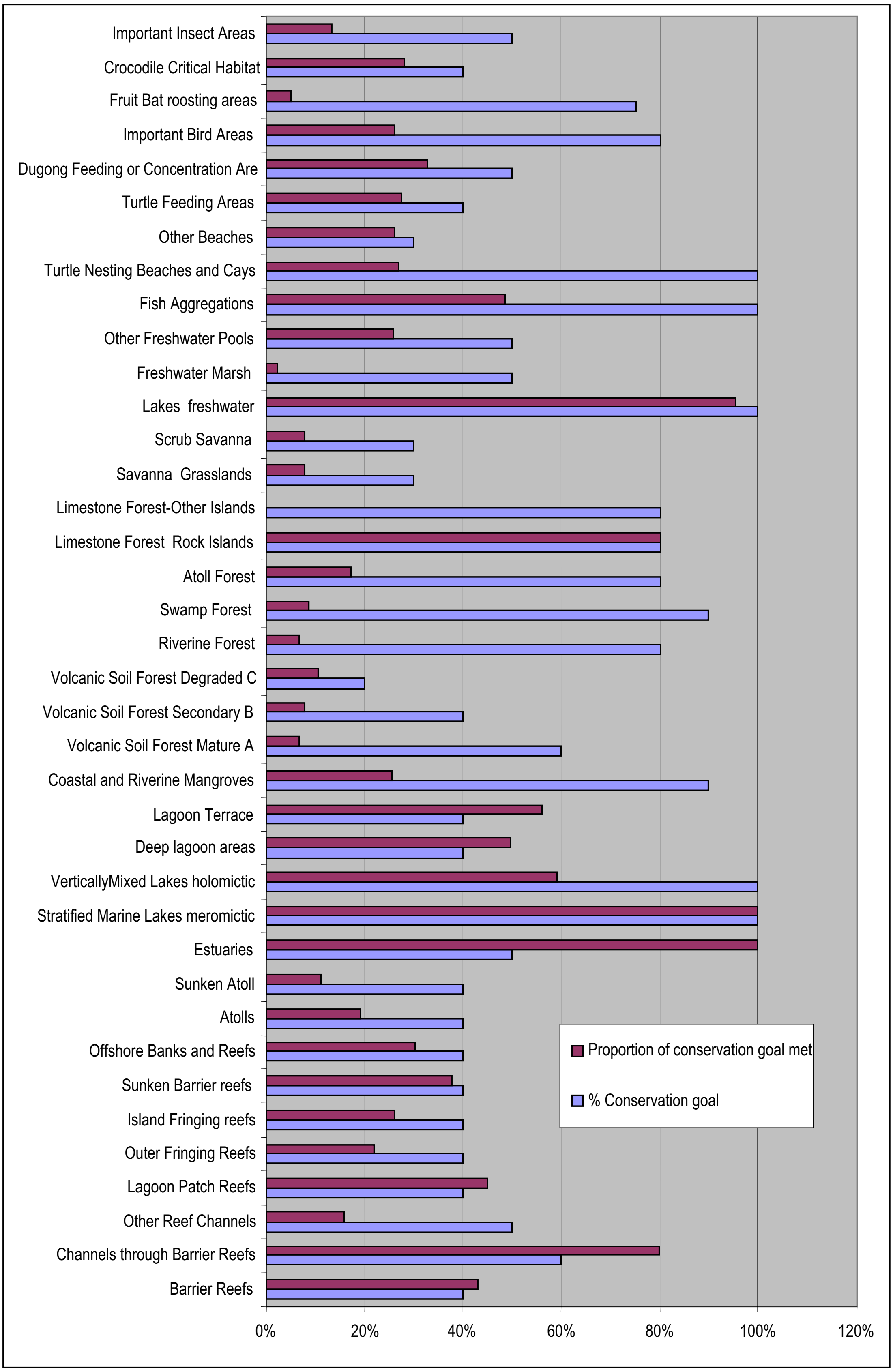


Figure 9. Conservation Goals met in existing Protected Areas

DATA GAPS

As explained in the process section of this report, this assessment was based primarily on coarse filter conservation targets, supported by a small subset of fine filter targets for special conservation features, such as nesting or breeding sites for individual species or groups of species. The primary reason for this approach was the limited information available for many species on Palau. Future biodiversity assessment work in Palau should aim to fill some of the critical species information gaps. In addition, the spatial information already available for the selected coarse-filter targets is of varying quality and could be improved to provide more detailed or more accurate analyses. Priorities for filling data gaps are suggested in outlined below in Table 7.

Table 7. Data Gaps for Conservation Targets

Identified Data Gap	Possible Solution
Coarse-filter targets	
There was recognition that the many of broad biodiversity surrogates defined for this exercise have limited scientific basis for the communities that they support. For example, the broad surrogate for fringing reefs is represented as a homogenous community whereas in reality there is variation in environmental, hydrological and geographic space.	Future work should incorporate more detailed classifications of marine systems currently being developed (for example through work by Dr. Patrick Colin of CRRF, PICRC and others). In addition, taxonomic inventories are needed across the selected biodiversity surrogate units to further understand the composition of these communities and how they vary across environmental, hydrological and geographic space (i.e. what are we really sampling from a biodiversity stand point and do our current design principles and selection processes in MARXAN capture the elements of biodiversity they are supposed to represent).
A better vegetation map with a more detailed classification and better ground-truthing, is needed.	The 1987 vegetation maps (based on 1976 aerial photography) were recently digitized and a new vegetation map is being prepared by the US Forest Service (based on forest inventory data and Quickbird image analysis). Together these two products should provide high quality vegetation mapping required for State-based assessments.
A finer analysis of vegetation types is needed to identify small or unique vegetation associations or habitats.	Could be derived from new vegetation maps – see above – together with targeted surveys of critical areas.
Data on the extent of priority areas where invasive species are impacting native vegetation communities also needs to be included	As part of the existing vegetation mapping exercise, include existing data on the aerial extent of major invasive areas
Need to better define and map freshwater streams to try to capture the likely variation within stream biodiversity in the absence of detailed stream surveys	Manual GIS classification of the streams layer, with ground-truthing. (e.g. Possible classes could be perennial streams, intermittent streams, streams linked to freshwater swamps, streams linked to freshwater lakes).
Marine sediment dynamics and sedimentary surrogates need to be incorporated within the coarse filter targets. Differing sediments or surficial geology and associated processes support very different communities. There was recognition that there was a lack of appropriate surrogates delineating combinations of surface geology and depth (i.e. a finer breakup of lagoon bottom environments into specific communities	Need to develop a biodiversity surrogate layer integrating bathymetry/depth and surficial geology as a means to enable the effective consideration of lagoon bottom communities

Identified Data Gap	Possible Solution
Fine-filter targets	
One of the fundamental limitations of this ERA is an absence of data or assessment of threatened species in Palau. While the broad surrogates and special features identified in Table 1 and 2 capture many of habitats required for most species, it does not address the specific issues associated with threatened species and the specific threatening processes associated with their demise.	Specific studies on key target species need to be developed and implemented over the next three years to address this issue. Species listed on the IUCN Red List (shown in Appendix 6) would be a suitable starting point for this work.
Spawning aggregation sites, key nursery areas and connecting areas need to be identified for all key species including: – Species of high commercial value (e.g. pelagics such as tuna) – Species of high significance (e.g. grouper) – Species of high community or traditional significance –	PICRC suggested that a major Packard Foundation grant would operate over the next three years to address some of these issues, however, it would be necessary to identify which components the grant would address and how we would fill those gaps not addressed by the Packard Foundation grant.
There is limited information on terrestrial species distribution, abundance or density (both fauna and flora). We especially need distribution information on rare or threatened endemic species, and information on bird and bat roosting sites.	Species survey work is needed, together with systematic collection of local/traditional knowledge.
There is almost no information on critical habits and minimum viable area for terrestrial species, or on the habitat requirements of various species.	Further research, especially for rare or endangered endemics.
Ecological processes, particularly aspects such as the role of keystone species such as grazers (parrot fish) need to be incorporated in the model	The MARXAN analysis team, in collaboration with the appropriate scientists need to develop ways to effectively incorporate physical oceanographic parameters into the model, particularly with regard to the delineation or consideration of source/sink areas or resilient/resistant areas for coral bleaching
Understanding of turtles, crocodiles and dugongs was patchy, and the temporal and ecological understanding of how these species operate in Palau is poorly understood.	Ongoing systematic data collection for these long lived species is needed in Palau. We currently have 18 months worth of data and some historic information.
There is limited data on insects at this stage.	Further survey work (building on preliminary surveys already done by the Belau National Museum) could produce insect distribution maps

There are also a number of data gaps related to development of the cost layer for the MARXAN analyses. Most of the data layers included in this analysis were coarse-filter targets, with only a small subset of fine-filter targets. The existing targets form a solid foundation for the preliminary identification of areas of biodiversity for potential inclusion in the Protected Areas Network. However, for the next iteration, fine scale targets and more detailed analyses will be required at State level to ensure the development of meaningful outcomes. Key factors for fine State based assessments include:

- Mapping of land tenure and population areas/density - Public/Private/Clan land
- Mapping of current and likely future natural resource use and development for mining, fisheries, subsistence, commercial resource-use
- Distribution of invasive species - previous surveys and reports have only documented presence or absence within large area units (e.g., Babeldaob, Koror, etc). It would be relatively easy to map distribution of selected key species (mainly along roads and other disturbed areas) using GPS and GIS
- Impact of the live fish trade as a negative impact/threat in the cost layer - need to develop a threat layer that provides an indication of the relative intensity of the collection of live fish for the aquarium trade
- Analysis and mapping of existing production/protection levels for State and traditional protected areas, and
- Mapping of key priority areas for threatened and endemic species.

CONCLUSIONS AND NEXT STEPS

The critical next step is to promote discussion amongst local communities, State and traditional leaders and the national government on areas that could be considered for inclusion in the Protected Areas Network. The ongoing biodiversity assessment process should be integrated within this overall process in order to address the States' concerns and involve State representatives effectively in the process.

GIS mapping and MARXAN analyses will need to be ongoing as the process of consultation and discussion within each State is undertaken and realistic boundaries of potential protected areas are developed. Considerable work will be needed to look at linking protected areas between States to avoid ending up with separate small isolated protected areas rather than the larger contiguous areas suggested by the results of this analysis. As areas are identified and designated they can be "locked in" to the analyses and used to gradually refine the network and track progress towards the conservation goals.

Analysis at the State level needs to look in more detail at socio-economic, cultural and resource management needs together with biodiversity conservation aims and objectives. One option is to use MARXAN analyses for the States at a much finer scale (e.g., 1-5 ha planning units) to look in more detail at these issues within each State. This option would require adequate technical resources to collect spatial data, prepare maps, undertake the necessary analysis and provide support thorough consultation and discussion amongst the stakeholders within each State (and discussion between States and with the national government).

An alternative option would be to base the initial selection of potential protected areas at the State level on local knowledge, consultation and discussion and then use the MARXAN analysis as a means of tracking progress towards national biodiversity goals. The current outputs from MARXAN analysis could be used to promote discussion within each State and also to look at options for linking protected areas across State borders. Subsequent iterations of the analysis would help refine and improve the information available to guide discussions.

To improve the MARXAN analysis, and the quality and detail of the outputs produced, there are a number of data gaps that need to be filled as described in the Data Gaps Section. Some of the work required to fill these gaps is already underway or almost complete. The recent vegetation mapping work and more detailed classification and mapping of marine systems will be available for inclusion in the State-based assessments within the next 12 months or so. Other gaps, such as a more detailed understanding of critical habitat areas for rare and endangered species, may take longer to fill. However, as the Protected Areas Network will continue to develop over a number of years, there will be time to refine the selection of areas for inclusion in the network by including improved information as it becomes available.

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APPENDICES

Appendix 1. Draft PAN Design Principles

Biophysical

The aim of the biophysical principles is to maximize biological objectives by taking into account key biological and physical processes. The following is a summary of these principles:

- Conserve representative examples of each biodiversity feature *(conservation target)*
- Include a "sufficient" number and area of each biodiversity feature, and spread them out geographically to reduce the chances that they will all be negatively impacted at the same time. Aim to include at least 3 replicated areas representing or exceeding the percentage goal of each biodiversity feature.
- Take a system wide approach that recognizes patterns of connectivity within and among ecosystems.
- Where possible, maximize the amount of connectivity between protected areas with minimal fragmentation.
- Where possible, include entire biological units (e.g. seamounts, watersheds), including a buffer around the core area of interest, and where entire biological units cannot be included, chose bigger vs. smaller areas.
- Where information is available, include a minimum area of each ecosystem and community type to ensure that all known communities and habitats that exist are protected.
- All else being equal, choose representative areas[5] based on knowledge (high biodiversity areas, complementarity) to maximize the number of species protected.
- Include special and unique areas, including:
    - Resident or transient species aggregations and nursery areas of large groupers, humphead wrasse, and other key species that ensure ecological processes including (e.g. Grazing/keystone species and other key ecosystem drivers).
    - Ensure the maintenance and enhancement of Marine lakes and associated communities, the Rock Islands and deep-water resources (e.g. deep water fish and invertebrates).
    - Choose areas that are more likely to be resistant or resilient to global environmental change (areas that may be more resistant or resilient to coral bleaching).
    - Marine mammal and reptile preferred habitats (breeding, resting, feeding areas and migratory corridors).
    - Nesting and roosting areas.
    - Areas that support high species diversity.
    - Areas that support species with very limited distribution and abundance.
    - Areas that are preferred habitats for other vulnerable species and endemic species.
- Conserve rare, threatened and endemic species (e.g. dugong, cetaceans, megapodes).
- All else being equal, include sites that are more likely to be resistant or resilient to threats and change.
- Consider sea and land use, particularly proximity to threats and other protected areas.
- Maximize acquisition and use of environmental information to determine the best configuration, recognizing the importance of connectivity in network design.
- Consider if patterns (distribution and status of community types) are the result of natural processes or anthropogenic affects.

[5] An area that is typical of the biodiversity feature within which it is located.

Socioeconomic

The aim of these principles is to maximize benefits and minimize costs to local communities and sustainable industries. The following is a summary of these principles. In some situations, specific strategies were identified to implement the principles.

General

- States and local communities play a central role in designation and management of PA.
- Recognize that local communities are local resource owners in the PAN network and will be involved in all decision-making processes.
- Traditional ownership of resources and terrestrial -land ownership
- Recognize and respect local resource owners and customary land tenure systems.
- Understand and incorporate local knowledge and traditional natural resource management and conservation practices.
- Areas that are locally important will be prioritized (e.g. areas for natural resource use, culturally important areas, socio-economically important areas, etc.).
- Minimize conflicting uses, such as tourism and extractive use.
- Minimize negative impacts on existing livelihood strategies.
- Protect areas of cultural importance to traditional owners.
- Consider current and future population trends and changing resource use.
- Ensure the costs and benefits of the network are fairly distributed within and between communities.
- Established protected areas (i.e. recognized by local regulations) should be regarded as 'focal points' "core areas" of an expanded system
- Consider PA effect on adjacent States (crocodiles, fish)
- Recognize limited geographic size of some of the States
    - States should not feel pressured
    - How do we work to make the States understand their in preserving Palau's biodiversity
- Incentives / assistance to the communities
- Allowing areas that are sustainably utilized
- Should we count traditional closures (bul) as part of the PAN and the Micronesia Challenge?
- National and States development plans should coincide with conservation/environmental goals
- Culture and environment need to be considered together equally/fairly

Resources

Work with communities to:

- Ensure PA supports sustainable subsistence and artisanal resource use for local communities by recognizing diverse livelihood strategies, and spatial and temporal variations in resource use and value
- Consider costs and benefits to local communities (and sustainable industries) in management of commercial resource use
- Conserve resources which local communities identify as important to their livelihood and have cultural significance
- Conserve resources for local communities by prohibiting destructive use methods
- Conserve resources for local communities by prohibiting unsustainable use particularly trade and other uses for species particularly vulnerable to overexploitation
- Recognize resources uses' benefits of PAs

Specific strategies should include:

- Enforcing National Fisheries Act Section 32(1-7) that prohibits the use of fishing with poisons or explosives, and working with local communities through education and awareness programs leading to the eventual prohibition of other destructive fishing methods.
- Prohibiting commercial fisheries for live reef food fish trade under the national management plan.
- Conserving spawning aggregations of large commercial fish species, particularly those targeted by the live reef food fish trade.
- Using closures to contribute to the management of commercial fisheries for invertebrates (particularly for trochus and beche de mer).

- Designating special management areas under Fisheries Act.
- Developing and implementing a provincial law that caters for fisheries management and conservation.
- Engaging in policy level discussions regarding fisheries policy in PNG, and WNB, which may benefit fisheries management.
- Prohibiting artisanal and commercial fishing for sharks and rays, and fishing or deliberate capture of cetaceans.

Nature Based Tourism

- Use PAN to provide opportunities for environmentally sound tourism to benefit local communities.
- Promote opportunities for sustainable tourism activities by local communities.
- Ensure that tourism activities are environmentally sustainable.
- Protect high priority tourism sites from conflicting (extractive or destructive) uses.
- Develop and implement best environmental guidelines for eco-tourism (diving, snorkeling, visiting islands).
- Ensure visiting tourism and recreational vessels are aware of PAN and regulations.
- Implement PAN management charges for the tourism industry to be used to support management of the PAN network.
- Incorporate national Tourism Plan. (new)

Road and Development Infrastructure

- Mitigate impact of the Compact Road through design of PAN in Babeldabo (avoid placing protected areas adjacent to road or factor in buffer areas where necessary.
- Involvement of regulatory bodies in design of development infrastructure and consideration of proposals.

Appendix 2. GIS Data Information Sources

Target Layers

Spatial Data Layers	Notes on Data Layers and Data Sources
Coral Reefs	
1. Barrier Reefs	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
2. Channels through Barrier Reefs	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
3. Other Reef Channels	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
4. Lagoon Patch Reefs	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
5. Outer Fringing Reefs	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
6. Island Fringing reefs	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
7. Sunken Barrier reefs	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
8. Offshore Banks and Reefs	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
9. Atolls	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
10. Sunken Atoll	Original maps from 1:25,000 USGS base maps held by PALARIS. Polygons updated from IMARS classifications.
Marine Water Resources	
11. Estuaries	One only - Ngeremeduu Bay - from USGS base map.
12. Stratified Marine Lakes (meromictic)	From PALARIS, derived from USGS base maps - classification into stratified/mixed from CRRF.
13. Vertically-Mixed Lakes (holomictic)	From PALARIS, derived from USGS base maps - classification into stratified/mixed from CRRF.
Lagoon and sediment Bottoms	
15. Deep lagoon areas	From IMARS classification
16. Lagoon Terrace	From IMARS classification
17. Algal Beds	PICRC remote sensing (David Idip)
18. Sea Grasses	PICRC remote sensing (David Idip)
Mangroves	
19. Coastal and Riverine Mangroves	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
Forest/Vegetation	
20. Volcanic Soil Forest, (Mature A)	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
21. Volcanic Soil Forest, (Secondary B)	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
22. Volcanic Soil Forest, (Degraded C)	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
23. Riverine Forest	Buffer on all streams with forest (Hydrology layer from PALARIS) Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
24. Swamp Forest	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
25. Atoll Forest	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
26. Limestone Forest - Rock Islands	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
27. Limestone Forest – Other Islands	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
28. Savanna / Grasslands	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)

Spatial Data Layers	Notes on Data Layers and Data Sources
29. Scrub Savanna	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
Fresh Water Resources	
30. Streams	Hydrology layer from PALARIS
31. Lakes - freshwater	Hydrology layer from PALARIS
32. Freshwater Marsh	Babeldaob Vegetation Map. Landsat 7 (2003) Tim Boucher, Michael Aulerio and Umiich Sengebau (2003)
33. Other Freshwater Pools	Hydrology layer from PALARIS
Other Special Targets	
34. Rocky Shores	Not available
35. Fish Aggregation Sites (Transient)	Local knowledge and surveys - mapped at expert workshops. Includes information from PALAU Rapid Ecological Assessment Report, PICRC and CRRF surveys.
36. Fish Aggregation Sites (Resident)	Local knowledge and surveys - mapped at expert workshops. Includes information from PALAU Rapid Ecological Assessment Report, PICRC and CRRF surveys.
37. Turtle Nesting Beaches and Cays	Local knowledge and surveys - mapped at expert workshops. Includes beaches mapped by the Turtle Project to date (May06) and previous mapping.
38. Other Beaches	From PALARIS base maps - based on USGS 1:25,000 base topographic maps.
39. Turtle Feeding Areas	Local knowledge and surveys - mapped at expert workshops.
40. Dugong Feeding or Concentration Areas	Local knowledge and surveys - mapped at expert workshops. Includes polygons from PCS dugong survey and interviews with fishermen. Also used sightings from 3 aerial dugong surveys to build polygons.
41. Important Bird Areas	Local knowledge and surveys - mapped at expert workshops (also IBA surveys conducted by PCS - see IBA report) – Terrestrial group
42. Fruit Bat roosting areas	Local knowledge and surveys - mapped at expert workshops (also IBA surveys conducted by PCS - see IBA report) – Terrestrial group
43. Nesting Cliffs and Caves	Local knowledge and surveys - mapped at expert workshops – Terrestrial group
44. Crocodile Critical Habitat	Local knowledge and surveys. Includes critical areas from Brazitis survey report, plus additional survey information by Eberdong. Also PCS crocodile survey maps.
45. Important Insect Areas	Expert info (from Alan Olsen) - based on his surveys and the Compact Road survey. Known areas only - incomplete data until further surveys conducted.

Other notes:

Velasco reef	Main reef classified as sunken atoll
	Sunken lagoon area and sunken patch reefs excluded from analysis

Cost Surface Layers

No.	Spatial Data Layers	Mapping status	Notes
	Positive for conservation		
1	Existing Protected Areas	Included	Mapped by PALARIS, TNC, PCS
2	Existing Protected Areas - large	Included	Rock island Conservation Area, Ngaruangel, Ngeremeduu Bay
3	Proposed Protected Areas	Included	Mapped by PCS and expert workshop.
4	Traditionally Managed Areas	Included	Mapped by PCS and expert workshop. Inlcudes Ngdull areas
5	Cultural / Historic sites	Included	From cultural site database.
6	Water Sources	Included	Includes lakes and ponds from target layers.
7	Upland Watersheds	Included	Upland areas (above 50m asl) within the major drainage basins identified in Compact Road EIS.
8	Taro Patches	Included	From cultural site database.
9	Dive Sites	Included	Points from PALARIS with 10 m buffer.
10	Tourism Sites	Included	Points from PALARIS with 10 m buffer.
11	Higher survival after 1998 bleaching	Included	From expert workshop – mapped by marine group
12	Better recovery since 1998 bleaching	Included	From expert workshop – mapped by marine group
13	Areas of known high coral diversity	Included	From expert workshop – mapped by marine group
14	Mangrove clam area	Included	From expert workshop - mapped by socio-economic group
	Negative Factors		
15	Near-shore Dredging	Included	From expert workshop - mapped by socio-economic group
16	Proposed Development	Included	From expert workshop - mapped by socio-economic group. Includes proposed development around new capital.
17	Existing aquaculture	Included	From expert workshop - mapped by socio-economic group
18	Proposed aquaculture	Included	From expert workshop - mapped by socio-economic group
19	Mining Sites / Quarry	Included	From expert workshop - mapped by socio-economic group
20	Compact Road	Included	From PALARIS.
21	Other Road	Included	From PALARIS.
22	New Capital Site	Included	From expert workshop - mapped by socio-economic group
23	Waste Disposal Sites	Included	From expert workshop - mapped by socio-economic group
24	Existing airports	Included	From Landsat image
25	Man-made features	Included	Includes schools, houses, cemeteries
26	Other existing developed areas	Included	Includes urban and bare ground from vegetation map.
27	Unsustainable farming	Not mapped	
28	Invasive Species	Not mapped	

Appendix 3. Notes on Conservation Targets and Nested Targets

Below is a brief description of each of the selected conservation targets. Source documents include: Cole et.al. (1987); Colin (2004); Hinchley and Sheppard (2004); and Maragos, et al. (1994).

Target	*Description (include comments on nested targets)*
1. Barrier reefs	***Barrier/Outer slope (below about 2 m depth):*** Occurring over much of Palau's outer edge, barrier reefs predominate in the north, west and some eastern areas of the main reef tract. High species diversity of corals and fishes, highly affected by bleaching, 90% plus mortality in some areas, causing a reduction in coral species diversity. Stable environments thermally. Clarity of water varies with the tide. Exposed to strong wave action at times, especially in shallower parts. Spawning sites for many smaller reef fishes with planktonic eggs, many aggregate to spawn in this zone on certain phases of the tide and lunar month. ***Barrier/ reef crest & top:*** Lower coral diversity than outer slope, not as affected by bleaching probably due to adaptation of corals there to high temperature stress at low tides. Strong tidal influence, often emergent or very shallow on spring low tides, currents vary with tide, moderate species diversity, high herbivory by fishes. Huge stands of Sargassum algae in many areas, may be a seasonal or periodic occurrence. ***Barrier/ lagoon slope:*** Protected from strong wave action, high effect from coral bleaching, moderate high diversity
2. Channels through barrier reefs	Complete and incomplete channels from ocean to lagoon, high coral diversity, highly affected by coral bleaching, high fish diversity, many are spawning aggregation sites for larger reef fishes such as groupers, seasonal and lunar periodicity to aggregation. Variable, often strong currents with tides.
3. Other reef channels	Most channels have rich biological communities on their sides. There are many filter-feeding organisms among them since the alternating currents simplify filter feeding. The dark tree coral, Tubastrea micrantha (T. cocinea of some authors) is common and reaches sizes of several meters tall. Whip gorgonians and other types of gorgonians are common. Some organisms thrive in strong currents, and certainly a different community should be expected on the sides and bottom of channels than occurs in protected reef waters.
4. Lagoon patch reefs	Generally protected from wave action and strong currents, moderate coral diversity, low to high coral cover, moderately affected by coral bleaching, moderate fish diversity.
5. Outer fringing reefs	Important habitat for many species of reef fish and corals. Also feeding grounds for turtles and dugongs. Found on east coast and more exposed to wind and wave action than the inner fringing reefs. Also fringing reefs in Rock Islands with moderate coral diversity, somewhat protected from coral bleaching, may be adapted for high temperatures, important bait fish resources in vicinity of these shores. Important habitat for small juvenile reef fish and giant clams and other marine species (i.e., turtles). Support coral communities, seagrass beds, sea cucumbers, crabs and shrimps.
6. Inner fringing reefs	West side of Babeldaob. Low coral diversity, but species resistant to sedimentation, high sedimentation, salinity variable, protected from wave action, little affected by coral bleaching. Important habitats for many species of reef fish that feed on the nutrient-rich waters. Also important habitats for endangered dugongs and saltwater crocodiles.
7. Sunken Barrier reefs	Many of the larger gaps in the barrier reef are areas where it might be considered "sunken". These are relatively shallow reefs (usually less than 10-15 m deep) which are part of the continuous lip of the barrier reef, just deeper by several meters than nearby areas of the shallow barrier reef. The communities on the sunken barrier reef are not well documented. In areas of hard bottom there is potential for coral communities. In places where the sunken barrier is a shallow sill in between long lengths of shallow barrier reef, there are lots of sand channels developed on its surface. Other areas such as the sunken barrier off the Ngerderaak-Lighthouse Reef area has patches of reef which rise up from a general sunken reef.
8. Offshore banks and reefs	Stable salinity and temperature, consistent, clear water, probably moderately high coral diversity, moderate coral cover, probable high fish diversity, not much really known about them, targets for possible oil development. Important habitat for many species of reef fish. Also important feeding ground for marine turtles. (Velasco Reef, Hydrographer Bank, etc.)
9. Atolls	There are three atolls in the Republic of Palau. Two (Kayangel and Ngeruangel/Velasco) are found in the northern part of the Republic, near the main Palau reef tract, while the third (Helen Reef) is

Target	Description (include comments on nested targets)
	some 360 nautical miles (500 km) southwest of the main islands. They are protected from terrestrial inputs and are stable environments with moderate diversity due to lack of many habitats. They have variable coral cover and are highly affected by coral bleaching. Important habitats for certain species of reef fish. Also important feeding and aggregating sites for marine turtles.
10.Sunken atolls.	Ngeruangel atoll is not a true atoll itself, but part of a larger complex called Velasco Reef, which is actually a "sunken" atoll. This complex is the northern-most reef of the Republic of Palau. Velasco. The reef rim of Velasco Reef is a complex habitat, with what many low relief sand channels interspersed with hard bottom without extensive coral. Patch reefs with dark borders, implying corals, algae and other benthic life occur on the lagoon slopes of the shallow rim. Other marine communities probably occur in the deeper portions of the lagoon. The geomorphology of the reef would imply that it has rich fisheries resources. In deeper areas of the lagoon, there may be significant sea grass beds, particularly *Halophila* sp., that are used for food by dugong.
11.Estuaries.	Variable salinity and turbidity, sediment/mud bottoms, crocodile and dugong habitat. Important habitat for crocodile and dugong. Also important habitat for many species of reef fish
12.Stratified Marine Lakes	Genetically isolated, many potential endemics, reduced tidal amplitude, very protected environments, potentially highly diverse, each lake different, important for tourism (e.g., Jellyfish Lake), usually with anoxic layer below 12-15 m. Important habitats for the stingless jellyfish and other small marine organisms. Includes Marine Lake mangroves - very protected from wave action, reduced tides, roots and branches covered in epifauna with high diversity, invertebrates in particular with high potential for endemics. Also habitat for saltwater crocodile.
13.Vertically-Mixed Lakes	Protected habitat, not totally isolated, but subject to filtering effect of fauna, some with substantial submarine connections to lagoon, each lake somewhat different, tidal amplitude dampened, some large lakes up to 60 m deep. Important habitats for stingless jellyfish, fish and other animals (i.e., saltwater crocodile). Includes Marine Lake mangroves - very protected from wave action, reduced tides, roots and branches covered in epifauna with high diversity, invertebrates in particular with high potential for endemics. Also habitat for saltwater crocodile.
15. Deep lagoon areas	The lagoon environment of Palau below about 15-25 m is not very well known. Generally dominated by sediment environments ranging from a soft gooey mud to relatively coarse sand. Given these factors, it might be thought the lagoon bottom is pretty much a uniform environment, with a relatively depauperate fauna. This is not really the case and it can be surprisingly rich although often species are widely scattered and not common. They are productive areas with microorganisms, usually algae, that serve as food for many animals which forage both on and in the bottom. Herbivores, such as parrotfishes and surgeonfishes, which are open to predation by a wide variety of larger fishes, shelter on reefs, but range over adjacent sands to feed on algal films.
16. Lagoon terrace	Includes a number of distinct zones occuring in the area behind barrier reefs. Generally dominated by sediment bottoms, but coral heads of various sizes also occur. Moving towards the lagoon the zone of small truncated coral heads diminishes into open sand and then larger coral patch reefs start occurring surrounded by sand.
17. Algal beds	Dominated by Halimeda algae with sediments made from plates, very coarse. Distinct fauna and flora, deeper than 25 m, but distribution not well known for Palau. One known meadow east of Ngederak Reef.
18. Seagrass beds	Shallow seagrass beds (dominated by Enhalis and Thalassia) are generally no more than about 2 m deep, variable environmental factors, nursery grounds for some species, turtle feeding habitat, important to communities for subsistence fishing (sea urchins, etc.) Important habitat for juvenile reef fish. Also feeding ground for marine turtles. The shallow seagrass beds are also important habitat for sea cucumbers and sea urchins. Deep seagrass beds (mixed species) are generally down to about 10-15 m in lagoons, dugong habitat. Seagrasses in northwest of Babeldaob important dugong feeding habitat. Ngederrak in Koror is considered to be one of two most important dugong habitats in Palau. In Peleliu, green sea turtles and occasionally dugongs feed among the seagrass. Large fish populations are supported by the seagrass
19. Coastal and Riverine Mangroves	There are 18 species of mangroves in Palau. Mangrove areas are habitat for a wide range of marine species including mangrove crabs, clams, mullet, shrimps, clams and the endangered saltwater crocodile. They are nursery ground for some fish species. They are also habitat for several bird species in Palau and useful plants such as Nypa palm and Cannon Ball trees. They also play a role in preventing coastal erosion and trapping sediment from terrestrial runoff. See Veg map: **Undisturbed**: areas coded MN, MN.R, **Disturbed**: MN.SV, MN.D

Target	***Description** (include comments on nested targets)*
20. Volcanic soil forest (Mature A)	The upland forests of Palau are Found on soils formed on volcanic rock and are the most species diverse in Micronesia. They include approximately 200 species endemic to Palau. Common tree species found include *Campnosperma brevipetiolata, Parinari corymbosa*, *Alphitonia carolinensis, Rhus taitensis, Elaeocarpus carolinensis, Semecarpus venenosus, Calophyllum inophyllum, Gmelina palawensis* and *Pterocarpus indicus.* Species commonly found in the understory of Palau's forests include the palm *Pinanga insignis,* and other plants including *Pandanus aimiriikensis, Ixora casei, Eugenia cuminii, Osmoxylon oliveri, Manilkara udoido, Symplocos racemosa,* and *Cyathea lunulata.* Within the upland forest vegetation type, there are many smaller ecological communities but these can not be consistently identified on the aerial photographs and have not been mapped. Upland forests are home to the Marianas fruit bat, a wide range of endemic and native bird species (including a number of possibly rare or threatened species). See Veg Map: **Undisturbed forest**: Includes all vegetation types coded UP & UP.SW & UP.PO. **Disturbed forest:** areas coded UP.SV/SV.BB/SV.G/\/CO/C and all the AG and CO classes. N.B. Have a look at the size/density classes? Also look at influence of different soil types and aspect on forest types?
21. Volcanic soil forest (Secondary B)	As above but largely secondary growth on previously cleared areas (prior to about 1945)
22. Volcanic soil forest (Disturbed C)	As above, but with higher levels of disturbance, some ongoing (fire, coconut plantings, other agricultural or invasive species)
23. Riverine forest	Part of upland forest, but minor changes in species mix and forest structure near streams. Generated by applying a buffer along streams within forest areas. (15m each side along larger streams. 5m along small streams)
24. Swamp forest	Swamp forests mostly occur at sea level, interior to a mangrove forest, but are also found on level sites along streams and in flat-bottomed valleys at higher elevations. The vegetative community is more diverse than the mangrove forest community. Functions of this ecosystem include runoff absorption and soil retention. See Veg Map : **Undisturbed forest**: Includes all vegetation types coded SW & SW.UP **Disturbed forest:** areas coded SW.CO/SV.BB/SV
25. Atoll forest	Found towards the interior of atolls and along sandy or rocky coasts of high islands. Although generally located behind the strand, atoll forest species are often mixed with the strand species, so the transition from strand to atoll forest is often gradual and indefinite. Many of the plants found in this type of forest are valuable sources of food products. Others are important sources of fiber for weaving and medicines. Veg map: **Undisturbed forest**: Areas coded AT & AT.LI & AT.CA. **Disturbed forest**: areas coded AT.SV/CO
26. Limestone forest - Rock Islands	Found mainly on the coral islands of Peleliu and Angaur. The species composition of this vegetation type varies but typically includes both scrubby and tall trees sometimes growing out of bare rock. The humus from decaying leaves and other debris provide a sustained cycling of nutrients. Species commonly found in the limestone forest include *Intsia bijuga*, *Psychotria* spp., and *Clerodendrum inerm.* Includes a number of rare endemic species. support many of the bird species of Palau such as the Micronesian pigeon, Palau fruit dove and Nicobar pigeon. Also supports large bat roosting sites. Veg map: **Undisturbed forest:** RI
27. Limestone Forest – other islands	Similar to limestone forest on Rock Islands but heavily disturbed during WWII and including mainly the more common species. Less disturbed limestone forest occurs in the hilly parts of northern Peleliu. On Angaur, areas of limestone forest are found interspersed among freshwater, and occasionally, saltwater depressions. Most of the plants found on Peleliu and Angaur have traditional and medicinal uses or serve as sources of food for the islands' residents. These forests also support populations of the only native non-marine mammal (i.e., Marianas fruit bat) found in Palau. Veg map: **Undisturbed forest**: Areas coded LI. **Disturbed forest**: areas coded LI.SV/CA/CO/SW
28. Savanna / grasslands	Found in open environments (hill tops) of Babeldaob. Some debate about extent of naturally occurring savannas compared with "human-made" savannas. White –breasted wood swallow found almost exclusively on the edges of savanna (upper areas). Veg map: **Undisturbed "natural"**: Areas coded G & G.S & G.P. **Disturbed areas**: G.B, G.CA, G.D, G.F, G.G (Check significance of G.F – are ferns a significant natural type e.g on bauxite soils?)
29. Scrub savanna	Found in open environments (hill tops) of Babeldaob in a mosaic with savanna grasslands.

Target	***Description*** *(include comments on nested targets)*
30. Streams	Approximately 44 species of freshwater fish inhabit the streams of Babeldaob, including two endemic gobies. Saltwater water crocodiles also use the streams as pathways between nesting and feeding sites.
31. Lakes - freshwater	Lake Ngardok and Ngerkall Pond are the two main bodies of water located on Babeldaob. These are important breeding ground for many Palau's faunas. Supports the saltwater Crocodile breeding populations and also the Australian gray duck.
32. Freshwater marsh	Typically retains water all the time. The vegetation is dominated by several native species including sedges and small scrophs. The edges of this environment are often cleared for taro cultivation and plantations. Supports many species of plants and animals that are highly dependent on water. Common moorhen
33. Other freshwater pools	Other freshwater pools includes all remaining water bodies derived from satellite imagery and other sources that were not (30) Freshwater Lakes or (31) Freshwater marsh.
34. Rocky shores	Carved and shaped by strong waves that continuously pound the shore. Important habitat for many small marine organisms (i.e., crabs). Important habitat small crabs and other marine organism. Also habitat for crocodile who utilizes the crevices of the rock islands to hide or rest.
35. Fish aggregation sites (Transient)	Transient FSA are composed of individuals that usually form seasonal aggregations over specific lunar cycles, with individuals potentially traveling up to several 10s or 100s of kilometers to reach a particular spawning site (Carter et al. 1994; Luckhurst 1998; Bolden 2000). Transient FSA are typically seasonal, as opposed to monthly, and form over periods of several days within two to several consecutive months. Transient aggregating species include most groupers and snappers, and some emperors. For Palau, the most well known transient spawners are the camouflage grouper, *Epinephelus polyphekadion,* brown-marbled grouper, *E. fuscoguttatus* and squaretail coral grouper, *Plectropomus areolatus*. (all aggregate at overlapping sites and times) (R. Hamilton pers. comm.).
36. Fish aggregation sites (Resident)	Resident FAS are composed of individuals that usually travel short distances (meters to 10s of meters) to spawning sites and spawn monthly and perhaps even daily throughout the year. Generally, there are relatively large numbers of resident FSA sites within a particular locale or region. Resident aggregating species include, as examples, some species of wrasse, rabbitfish and surgeonfish (R. Hamilton pers. comm.).
37. Turtle nesting beaches and cays	Critical for turtle conservation. Nesting beaches are few in numbers and thus if protected will ensure the sustainable population numbers for Palau marine turtles.
38. Other beaches	Includes all other beach areas. Highly dynamic, important for tourism, and habitat for land crabs and other organisms (i.e., shell fish) Also megapodes and some nesting sea birds.
39. Turtle feeding areas	Resident, nesting species. Endangered - Protecting the feeding areas of the marine turtles will also ensure the protection of dugong habitat and aggregation sites. Furthermore, many species of reef fish will be protected as well.
40. Dugong feeding or concentration areas	Endangered species (IUCN redlist). One of the most isolated populations in the world, and may not be getting any new recruits from other areas. Very slow breeding. Culturally important in Palau and still under some hunting pressure.
41. Important Bird Areas	Local knowledge and surveys - mapped at expert workshops.
42. Fruit Bat roosting areas	Keystone species (seed dispersal etc). Hunting pressure. Declining? Endemic.
43. Nesting cliffs and caves	Birds – swiftlets Insectivorous bats – sheath-tailed bats
44. Crocodile nesting areas / corridors	Endangered species (IUCN redlist). Crocodiles use a range of habitats and range from sea to land to freshwater (linking systems).
45. Important insect areas	Local knowledge and surveys - mapped at expert workshops.

Appendix 4. Threats

Key threats to each of the conservation targets are briefly outlined below.

Target	**Key Threats**
System and Community	
1. Barrier reefs	Heavy fishing pressure from a complex combination of subsistence, commercial and recreational fishing. Some destructive fishing practices such as night spear fishing. Occasional ship groundings cause intensive damage at particular sites (but over a limited area). Coral bleaching (exacerbated by global climate change?) Damage to reefs from natural causes (e.g typhoons, crown of thorns starfish) Damage from tourism activities in some areas (mainly diving and snorkeling)
2. Channels through barrier reefs.)	As above
3. Other Reef Channels	As above. Also sedimentation and pollution for reefs close to shore.
4. Lagoon patch reefs	Sedimentation and water pollution from land-based activities(e.g. soil erosion, sewage) Anchor damage from fishing and tour boats. Coral bleaching (exacerbated by global climate change?) Heavy fishing pressure from a complex combination of subsistence, commercial and recreational fishing.
5. Outer fringing reefs	Sedimentation from land-based erosion in some areas. Intensive damage over small areas from dredging activities (and associated sediment movement). Coral bleaching (exacerbated by global climate change?) Natural causes (e.g typhoons, crown of thorns). Heavy fishing pressure from a complex combination of subsistence, commercial and recreational fishing.
6. Island fringing reefs	Sedimentation from compact road construction and other developments. Intensive damage over small areas from dredging activities (and associated sediment movement). Heavy fishing pressure from a complex combination of subsistence, commercial and recreational fishing.
7. Sunken barrier reefs	Fishing pressure. Coral bleaching (exacerbated by global climate change?)
8. Offshore banks and reefs (Velasco Reef, Hydrographer Bank, etc.)	Climate change, bleaching Natural causes (e.g typhoons, crown of thorns starfish).
9. Atolls	Heavy fishing pressure from a complex combination of subsistence, commercial and recreational fishing. Some destructive fishing practices such as night spear fishing. Coral bleaching (exacerbated by global climate change?) Natural causes (e.g typhoons, crown of thorns starfish) Tourism activities in some areas (mainly diving and snorkeling)
10. Sunken Atolls	Coral bleaching (exacerbated by global climate change?) Natural causes (e.g typhoons, crown of thorns starfish) Tourism activities in some areas (mainly diving and snorkeling)
11. Estuaries	Sedimentation from road construction and other land-based developments Water pollution (e.g. oil from motorized boats, sewage) Fishing pressure
12. Stratified Marine Lakes	Tourist-related activities (i.e., swimming and snorkeling, pollution, littering) Climatic changes (e.g., water temperature associated with El Nino). Introduction of alien species.
13. Vertically-Mixed Lakes	See threats for previous target.
15. Deep lagoon areas	Fishing pressure.
16. Lagoon terrace	Fishing pressure.

Target	Key Threats
17. Algal beds	Fishing pressure.
18. Seagrass beds	Sedimentation from land developments, Water pollution (e.g. sewage and oil spills, motorized boats) Dredging activities.
19. Coastal and Riverine Mangroves	Direct loss resulting from clearing and filling for urban and industrial development or tourism. Sedimentation from roads, agriculture and development projects. Fishing pressure. Harvest pressures for other natural resources (crustaceons, timber)
20. Volcanic soil forest (Mature)	Forest loss and fragmentation resulting from poorly planned new development and road construction. Invasive species – a wide range of plant species, and animals such as pigs, cane toads Impacts of fire on fringes of forest (repeated burning of savanna areas) – and may be exacerbated by increased fragmentation and climate change.
21. Volcanic soil forest (Secondary)	As above
22. Volcanic soil forest (Degraded)	As above.
23. Riverine forest	As above
24. Swamp forest	As above. Also sedimentation associated with erosion from upstream areas caused by road construction and clearing for developments.
25. Atoll forest	Forest loss through development pressures as space on an atoll is limited. This type of forest is also vulnerable and can easily be damaged by strong winds.
26. Limestone forest - Rock Islands	Introduction of alien species and climatic changes are the main potential threats.
27. Limestone Forest - Other islands (Anguar, Peleliu)	Forest loss through development pressures from residential and commercial developers. Invasive species.
28. Savanna / grasslands	Clearing and burning for farming purposes. Clearing for road construction and residential and commercial developments. Repeated burning results in change in species mix and soil loss.
29. Scrub savanna (shrubland?)	As above
30. Streams	Sedimentation resulting from land use practices (i.e., clearing and burning), road construction and other infrastructure developments. Other water pollution – sewage, urban and industrial runoff
31. Lakes - freshwater	Currently in protected areas, but minor threats from invasives and potential development on fringes of area.
32. Freshwater marsh	Sedimentation resulting from land use practices (i.e., clearing and burning), road construction and other infrastructure developments. Conversion to agriculture (taro farming)
33. Other freshwater pools	Sedimentation or total loss resulting from land use practices (i.e., clearing and burning), road construction and other infrastructure developments.
34. Rocky shores	No significant threats.
35. Fish aggregation sites (Transient)	Overfishing during aggregation periods is the key threat. Also disturbance from tourism activities.
36. Fish aggregation sites (Resident)	Overfishing during aggregation periods is the key threat. Also disturbance from tourism activities.
37. Turtle nesting beaches and cays	Loss of eggs to poachers. Disturbance of nest by people using beaches. Invasive species (e.g. rats on tourist beaches)
38. Other Beaches	Structural developments encroaching the beaches. Pollution (i.e. wastewater and solid waste on tourist beaches) Removal of sand for construction projects or through erosion caused by boat traffic in some areas. Invasive species (e.g. rats on tourist beaches)

Target	**Key Threats**
39. Turtle feeding areas	Hunting of turtles for food. Disturbance or damage to turtles from tourism activities, boat traffic and associated pollution (e.g plastic bags).
40. Dugong feeding or concentration areas	Death of dugongs caused by boat traffic and occasional hunting. Declining water quality in some areas resulting from land-based sediment runoff and dredging. Decline in sea-grass because of sedimentation may also be an issue.
41. Important bird areas	Forest loss and fragmentation resulting from poorly planned new development and road construction. Invasive species – a wide range of plant species, and animals such as pigs, cane toads Hunting for some bird species.
42. Fruit Bat roosting areas	Hunting for food. Habitat loss resulting from poorly planned new development and road construction.
43. Nesting cliffs and caves	Quarrying for road construction and development.
44. Crocodile Critical Habitat	Loss of habitat to development in mangroves or in breeding ponds behind mangroves (roading, urban and industrial development). Occasional hunting.
45. Important insect areas.	Habitat loss resulting from poorly planned new development and road construction. Invasive species. Repeated burning of some areas.

Appendix 5. Scenario Summary Table

Target name	Total Area of Target (ha)	Conservation Goal %	% of Target Area Captured Under Each Scenario								
			Scenario 1	Scenario 2		Scenario 3		Scenario 4		Scenario 5	
				Lock-ins	All	Lock-ins	All	Lock-ins	All	Lock-ins	All
Barrier Reefs	43,718	40%	40%	43%	57%	43%	57%	43%	57%	43%	57%
Channels through Barrier Reefs	762	60%	77%	80%	94%	81%	95%	83%	94%	80%	95%
Other Reef Channels	1,089	50%	55%	16%	54%	19%	54%	19%	54%	16%	56%
Lagoon Patch Reefs	4,908	40%	42%	45%	68%	45%	66%	45%	66%	45%	66%
Outer Fringing Reefs	4,985	40%	40%	22%	43%	38%	51%	38%	50%	22%	42%
Island Fringing reefs	14,592	40%	54%	26%	59%	26%	60%	30%	60%	26%	58%
Sunken Barrier reefs	3,992	40%	41%	38%	62%	38%	62%	38%	62%	38%	62%
Offshore Banks and Reefs	1,245	40%	40%	30%	46%	30%	50%	36%	52%	30%	48%
Atolls	11,126	40%	43%	19%	48%	20%	49%	21%	49%	19%	48%
Sunken Atoll	18,353	40%	40%	11%	40%	11%	40%	11%	40%	11%	40%
Estuaries	463	50%	52%	100%	100%	100%	100%	100%	100%	100%	100%
Stratified Marine Lakes meromictic	79	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
VerticallyMixed Lakes holomictic	23	100%	100%	59%	100%	59%	100%	61%	100%	59%	100%
Deep lagoon areas	115,838	40%	40%	50%	68%	50%	68%	50%	68%	50%	68%
Lagoon Terrace	13,563	40%	40%	56%	72%	61%	75%	61%	75%	56%	72%
Coastal and Riverine Mangroves	4,724	90%	90%	25%	90%	27%	90%	28%	90%	26%	90%
Volcanic Soil Forest Mature A	10,024	60%	67%	7%	67%	7%	67%	21%	70%	51%	75%
Volcanic Soil Forest Secondary B	8,681	40%	61%	8%	62%	8%	62%	17%	64%	38%	70%
Volcanic Soil Forest Degraded C	2,754	20%	53%	11%	56%	11%	56%	14%	58%	29%	66%
Riverine Forest	682	80%	80%	7%	80%	7%	80%	21%	80%	46%	80%
Swamp Forest	1,928	90%	90%	9%	90%	10%	90%	11%	90%	9%	90%
Atoll Forest	594	80%	81%	17%	81%	20%	81%	28%	80%	17%	80%
Limestone Forest Rock Islands	6,115	80%	80%	80%	90%	80%	89%	80%	90%	80%	89%
Limestone Forest-Other Islands	1,029	80%	80%	0%	80%	0%	80%	0%	80%	0%	80%
Savanna Grasslands	6,301	30%	38%	8%	41%	8%	41%	10%	40%	25%	49%
Scrub Savanna	1,585	30%	55%	8%	56%	9%	56%	13%	57%	25%	59%
Lakes freshwater	6	100%	100%	96%	100%	96%	100%	96%	100%	96%	100%
Freshwater Marsh	112	50%	90%	2%	98%	2%	97%	2%	95%	2%	98%
Other Freshwater Pools	18	50%	67%	26%	78%	26%	68%	26%	66%	26%	68%
Fish Aggregations	13,391	100%	100%	49%	100%	49%	100%	53%	100%	49%	100%
Turtle Nesting Beaches and Cays	53	100%	100%	27%	100%	36%	100%	36%	100%	27%	100%
Other Beaches	57	30%	72%	26%	80%	37%	82%	37%	83%	26%	74%
Turtle Feeding Areas	122,548	40%	45%	28%	56%	28%	57%	29%	57%	28%	56%
Dugong Feeding or Concentration Are	45,977	50%	50%	33%	60%	34%	60%	36%	60%	33%	60%
Important Bird Areas	22,034	80%	80%	26%	83%	26%	83%	37%	83%	61%	87%
Fruit Bat roosting areas	13,366	75%	79%	5%	79%	5%	80%	23%	80%	60%	91%

Target name	Total Area of Target (ha)	Conservation Goal %	% of Target Area Captured Under Each Scenario								
			Scenario 1	Scenario 2		Scenario 3		Scenario 4		Scenario 5	
				Lock-ins	All	Lock-ins	All	Lock-ins	All	Lock-ins	All
Crocodile Critical Habitat	7,289	40%	79%	28%	81%	31%	81%	33%	79%	29%	80%
Important Insect Areas	14,555	50%	79%	13%	81%	13%	82%	29%	81%	63%	91%

Appendix 6. Threatened Species

The IUCN Redlist provides the details on the current global listing on the status of threatened species[6].

Terrestrial Red List species

GROUP	SPECIES NAME	STATUS
Mammal	*Pteropus pilosus*	EX ver 2.3 (1994)
Mollusc	*Partula thetis*	CR A1c ver 2.3 (1994)
Mollusc	*Partula calypso*	CR A2c ver 2.3 (1994)
Mollusc	*Partula leucothoe*	CR A2e ver 2.3 (1994)
Mammal	*Emballonura semicaudata*	EN A1ac ver 2.3 (1994)
Mammal	*Pteropus mariannus*	EN A1cd+2cde ver 2.3 (1994)
Cycad	*Cycas micronesica*	EN A3ce ver 3.1 (2001)
Bird	*Megapodius laperouse*	EN B1ab(ii,iii,iv,v) ver 3.1 (2001)
Plant	*Aglaia mariannensis*	VU A1c ver 2.3 (1994)
Plant	*Pericopsis mooniana*	VU A1cd ver 2.3 (1994)
Plant	*Parkia parvifoliola*	VU D2 ver 2.3 (1994)
Bird	*Caloenas nicobarica*	NT ver 3.1 (2001)
Bird	*Ducula oceanica*	NT ver 3.1 (2001)
Bird	*Gallicolumba canifrons*	NT ver 3.1 (2001)
Bird	*Limosa limosa*	NT ver 3.1 (2001)
Bird	*Megazosterops palauensis*	NT ver 3.1 (2001)
Plant	*Horsfieldia palauensis*	LR/nt ver 2.3 (1994)
Mammal	*Macaca fascicularis*	LR/nt ver 2.3 (1994)

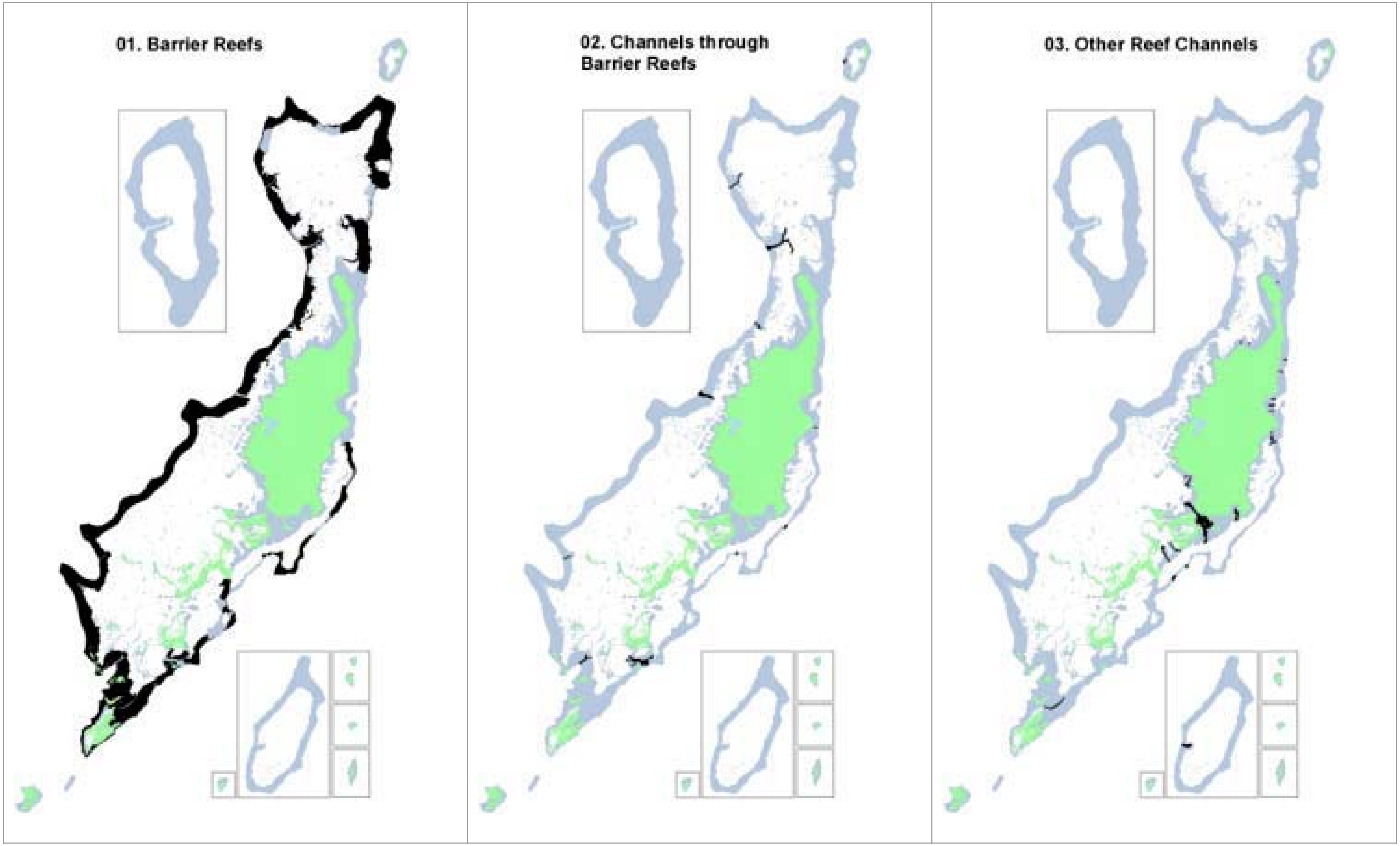
Marine Red List species

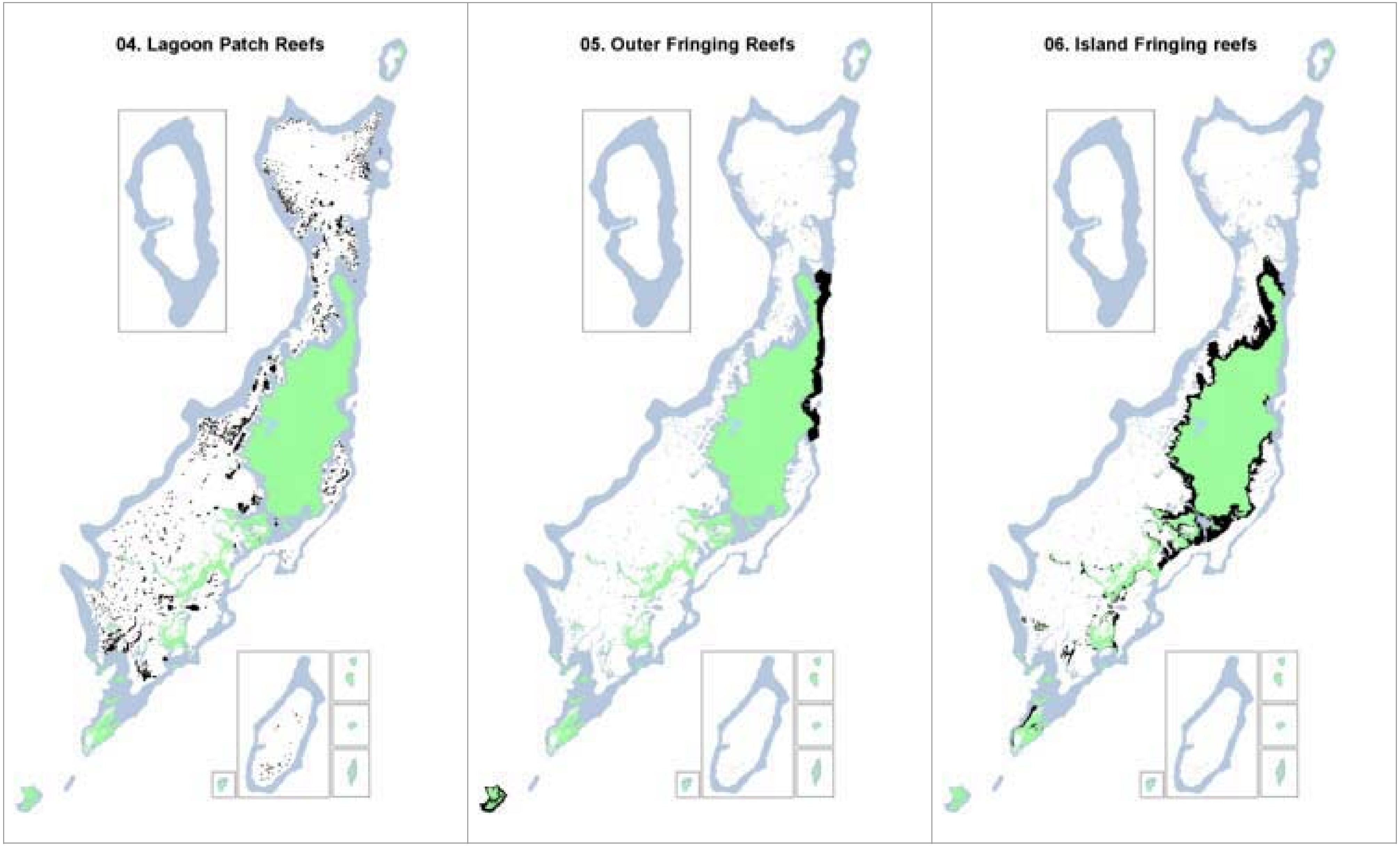
COMMON NAME	SPECIES NAME	STATUS
Hawksbill Turtle	*Eretmochelys imbricata*	CR A1bd ver 2.3 (1994)
Napoleon Wrasse	*Cheilinus undulatus*	EN A2bd+3bd ver 3.1 (2001)
Green Turtle	*Chelonia mydas*	EN A2bd ver 3.1 (2001)
Oceanic Whitetip Shark	*Carcharhinus longimanus*	VU A2ad+3d+4ad ver 3.1 (2001)
Dugong	*Dugong dugon*	VU A2bcd ver 3.1 (2001)
Giant Grouper	*Epinephelus lanceolatus*	VU A2d ver 3.1 (2001)
Tawny Nurse Shark	*Nebrius ferrugineus*	VU A2abcd+3cd+4abcd ver 3.1 (2001)
Leopard Shark	*Stegostoma fasciatum*	VU A2abcd+3cd+4abcd ver 3.1 (2001)
Bigeye Tuna	*Thunnus obesus*	VU A1bd ver 2.3 (1994)

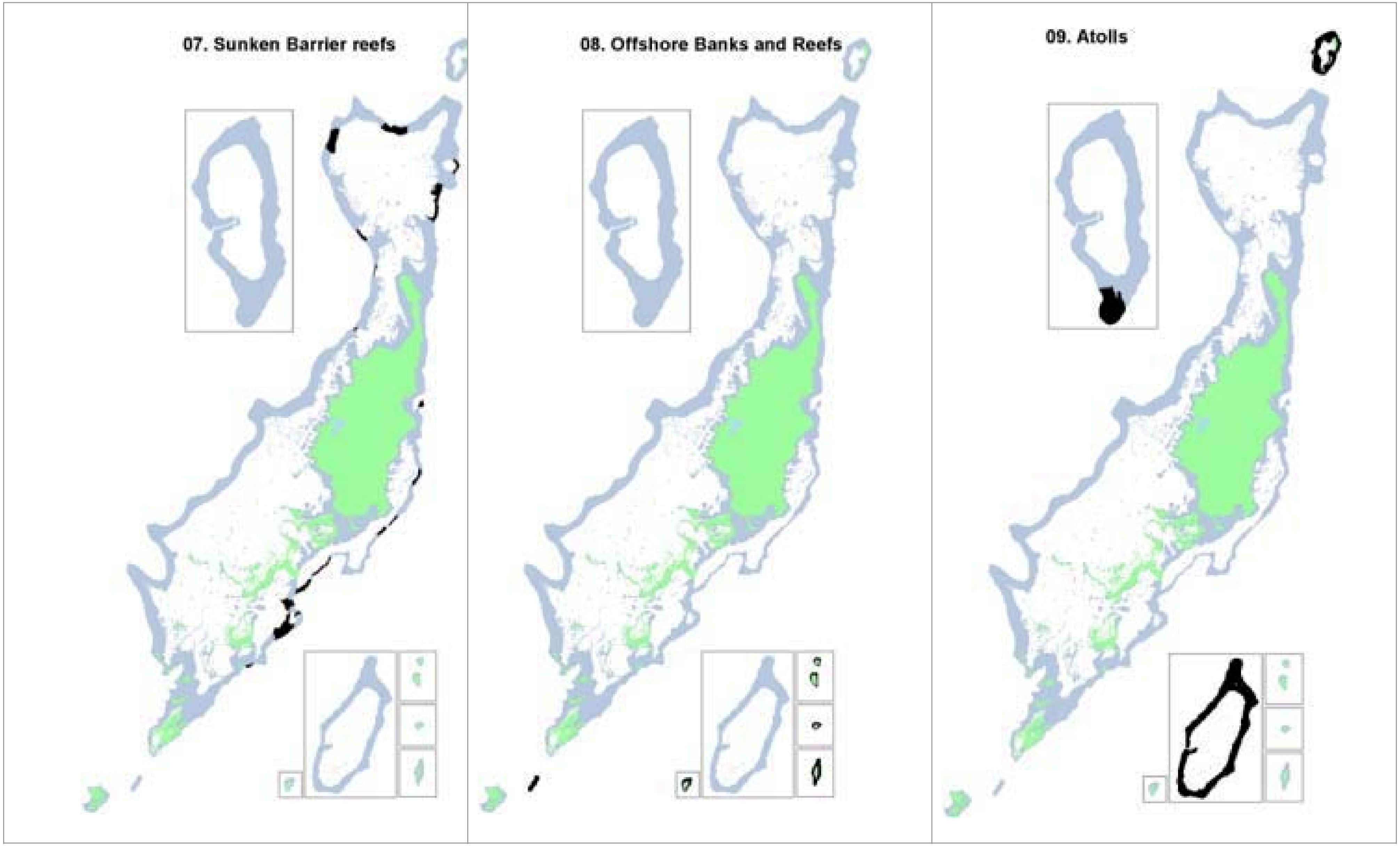
[6] See IUCN Red List http://www.iucnredlist.org Status categories: Extinct (EX), Extinct in the wild (EW), Critically Endangered (CR), Endangered (E), Vulnerable (V), Near threatened (NT), Least Concern (LC), Lower Risk conservation dependent (LR/cd), Lower Risk near threatened (LR/nt).

COMMON NAME	SPECIES NAME	STATUS
Southern Giant Clam	*Tridacna derasa*	VU A2cd ver 2.3 (1994)
Giant Clam	*Tridacna gigas*	VU A2cd ver 2.3 (1994)
Porcupine Ray	*Urogymnus asperrimus*	VU A1bd, B1+2bcd ver 2.3 (1994)
Prickly Shark	*Echinorhinus cookei*	NT ver 3.1 (2001)
Estuary Cod	*Epinephelus coioides*	NT ver 3.1 (2001)
Brown-Marbled Grouper	*Epinephelus fuscoguttatus*	NT ver 3.1 (2001)
Malabar Grouper	*Epinephelus malabaricus*	NT ver 3.1 (2001)
Camouflage Grouper	*Epinephelus polyphekadion*	NT ver 3.1 (2001)
Manta Ray	*Manta birostris*	NT ver 3.1 (2001)
Coral Trout	*Plectropomus leopardus*	NT ver 3.1 (2001)
Bear Paw Clam	*Hippopus hippopus*	LR/cd ver 2.3 (1994)
China Clam	*Hippopus porcellanus*	LR/cd ver 2.3 (1994)
Long-Beaked Dolphin	*Stenella longirostris*	LR/cd ver 2.3 (1994)
Small Giant Clam	*Tridacna maxima*	LR/cd ver 2.3 (1994)
Fluted Clam	*Tridacna squamosa*	LR/cd ver 2.3 (1994)
Gray Reef Shark	*Carcharhinus amblyrhynchos*	LR/nt ver 2.3 (1994)
Blacktip Reef Shark	*Carcharhinus melanopterus*	LR/nt ver 2.3 (1994)
Broadhead Sleeper	*Eleotris melanosoma*	LR/nt ver 2.3 (1994)
Tiger Shark	*Galeocerdo cuvier*	LR/nt ver 2.3 (1994)
Bluntnose Sixgill Shark	*Hexanchus griseus*	LR/nt ver 2.3 (1994)
Shortfin Mako	*Isurus oxyrinchus*	LR/nt ver 2.3 (1994)
Blue Shark	*Prionace glauca*	LR/nt ver 2.3 (1994)
Whitetip Reef Shark	*Triaenodon obesus*	LR/nt ver 2.3 (1994)

Appendix 7. Target GIS Layers



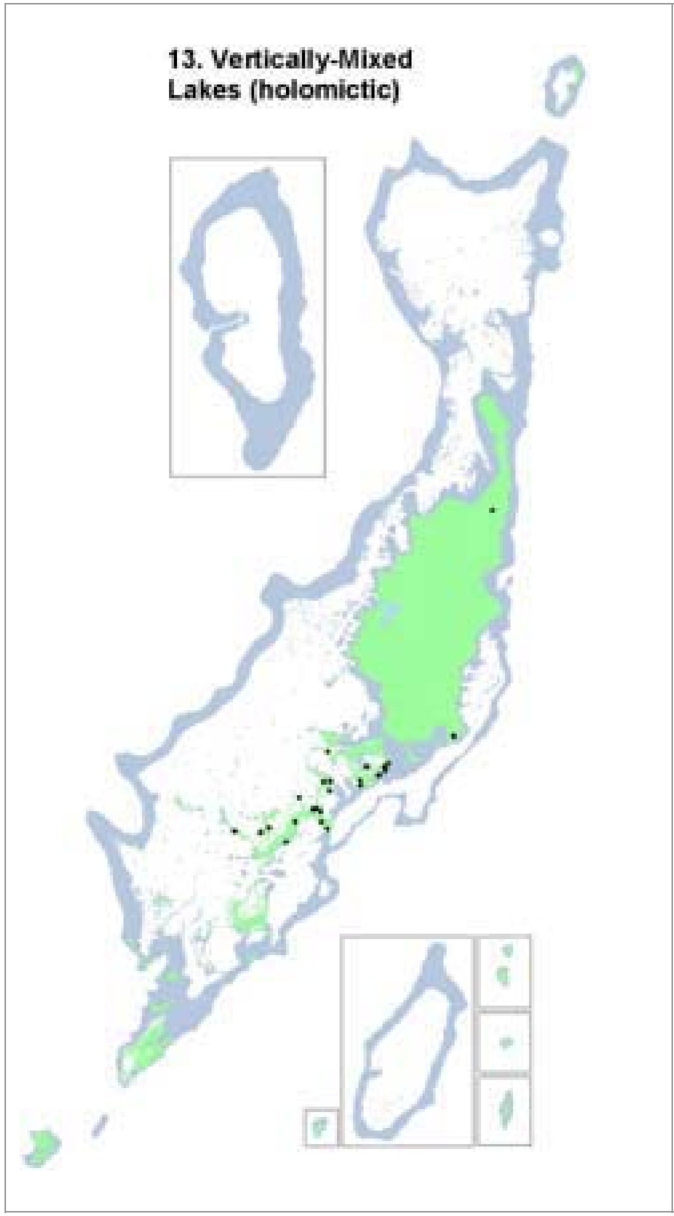

04. Lagoon Patch Reefs
05. Outer Fringing Reefs
06. Island Fringing reefs

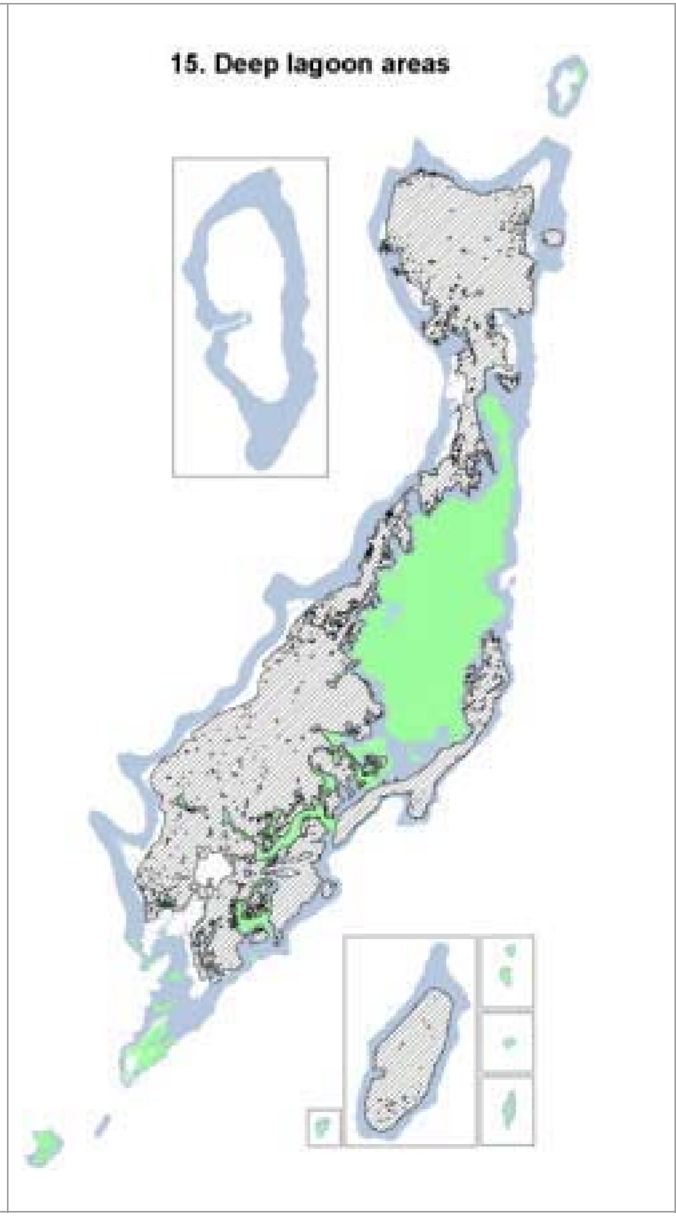

07. Sunken Barrier reefs
08. Offshore Banks and Reefs
09. Atolls

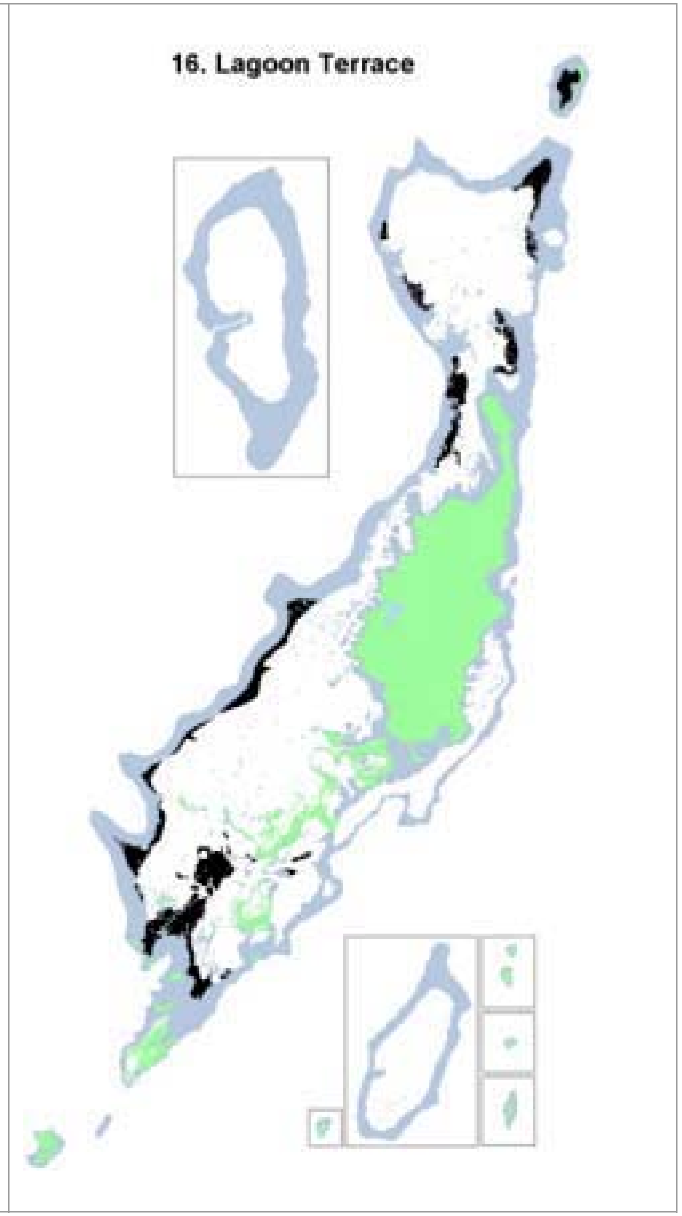
10. Sunken Atoll

11. Estuaries

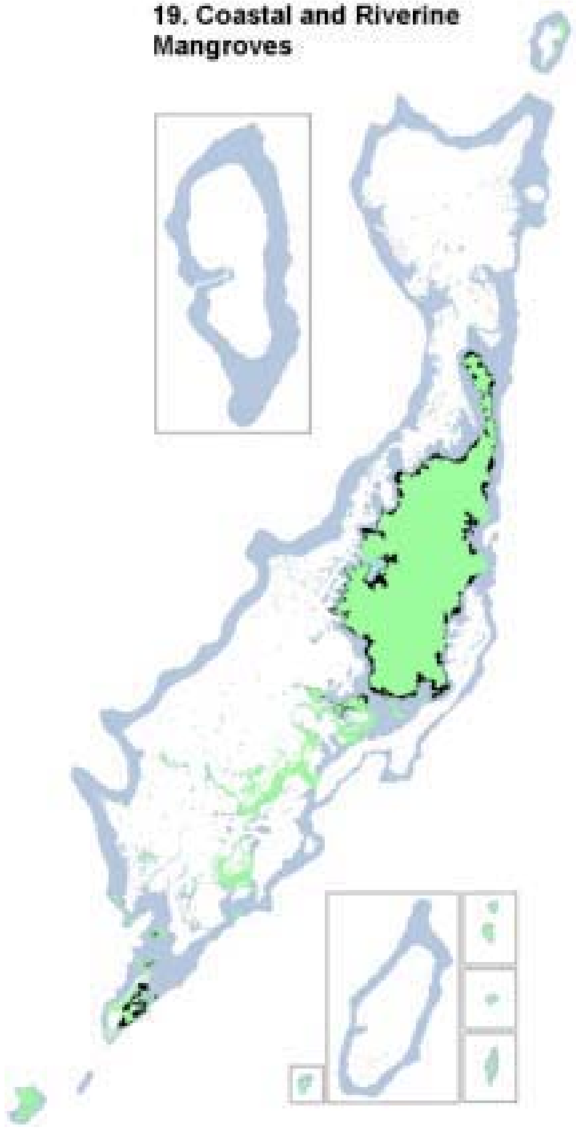
12. Stratified Marine Lakes (meromictic)


13. Vertically-Mixed Lakes (holomictic)

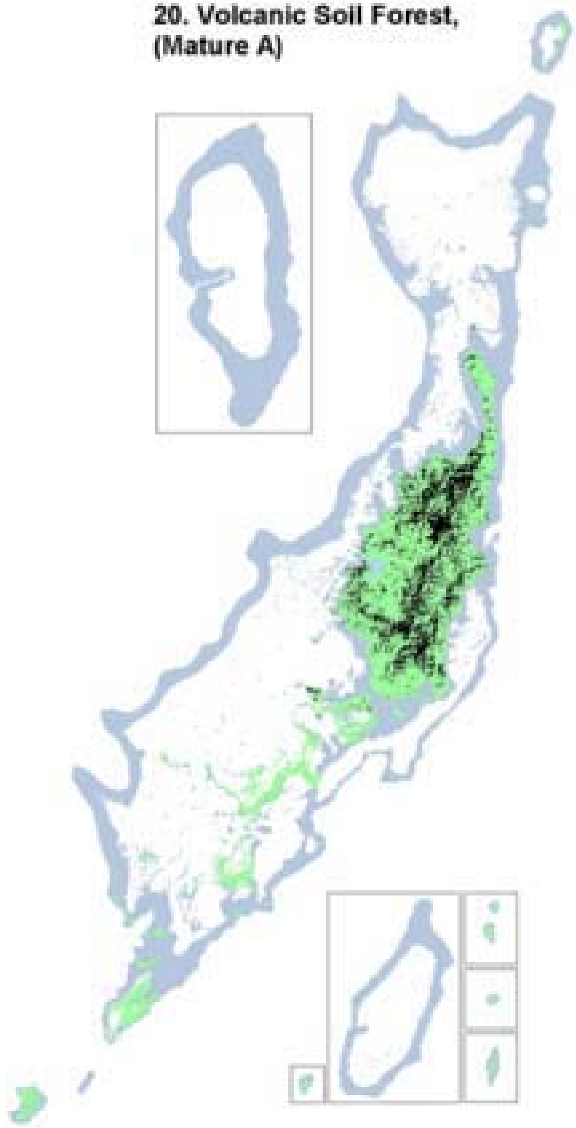

15. Deep lagoon areas


16. Lagoon Terrace

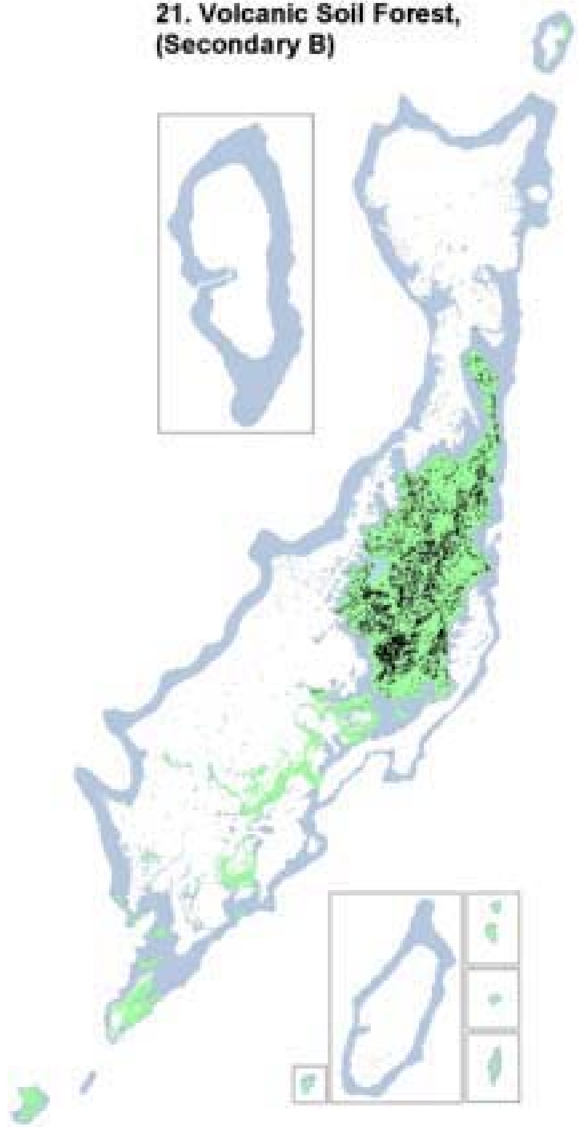
19. Coastal and Riverine Mangroves



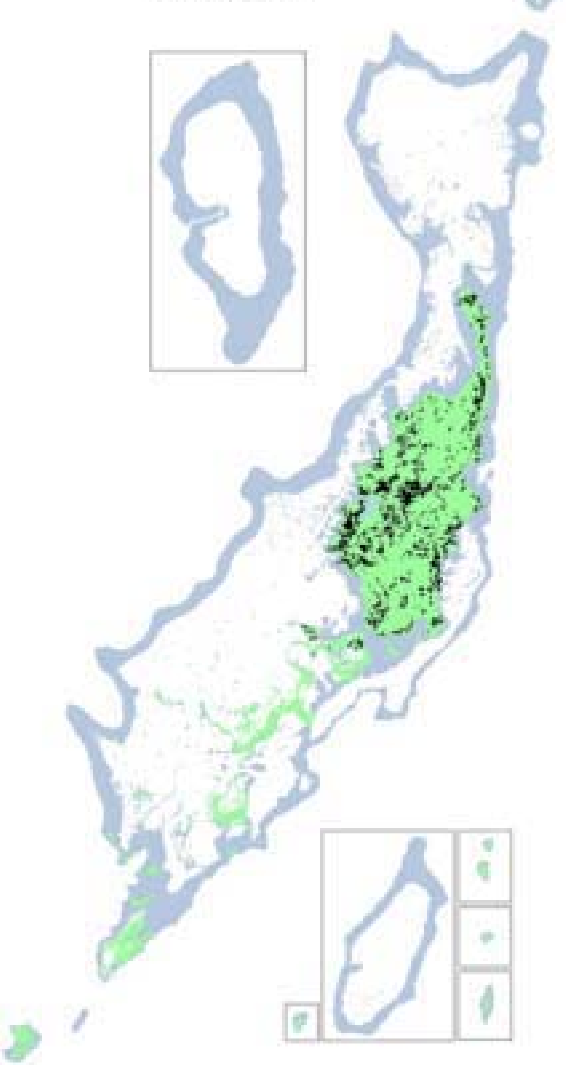
20. Volcanic Soil Forest, (Mature A)



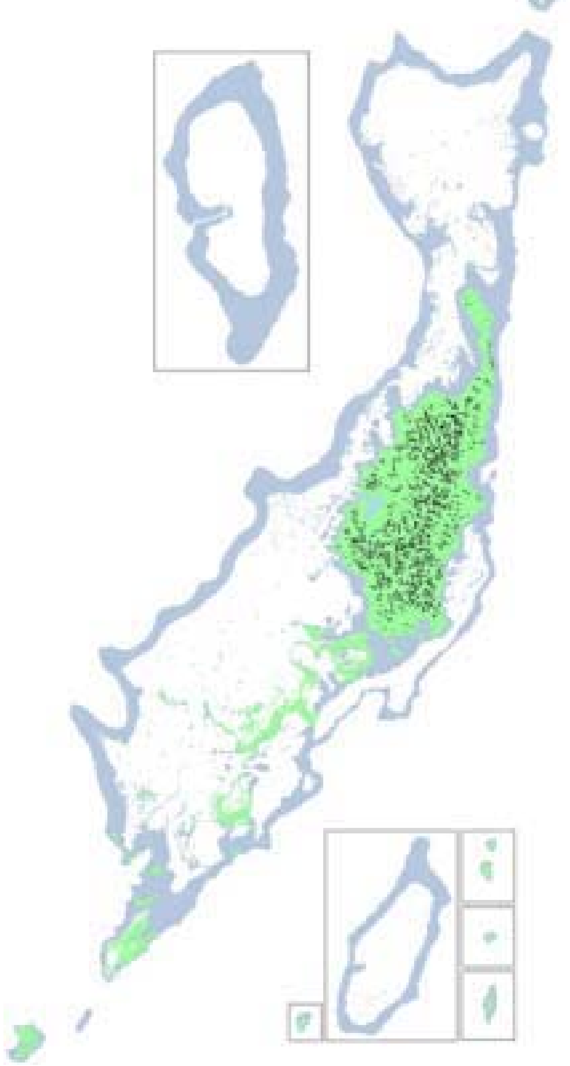
21. Volcanic Soil Forest, (Secondary B)



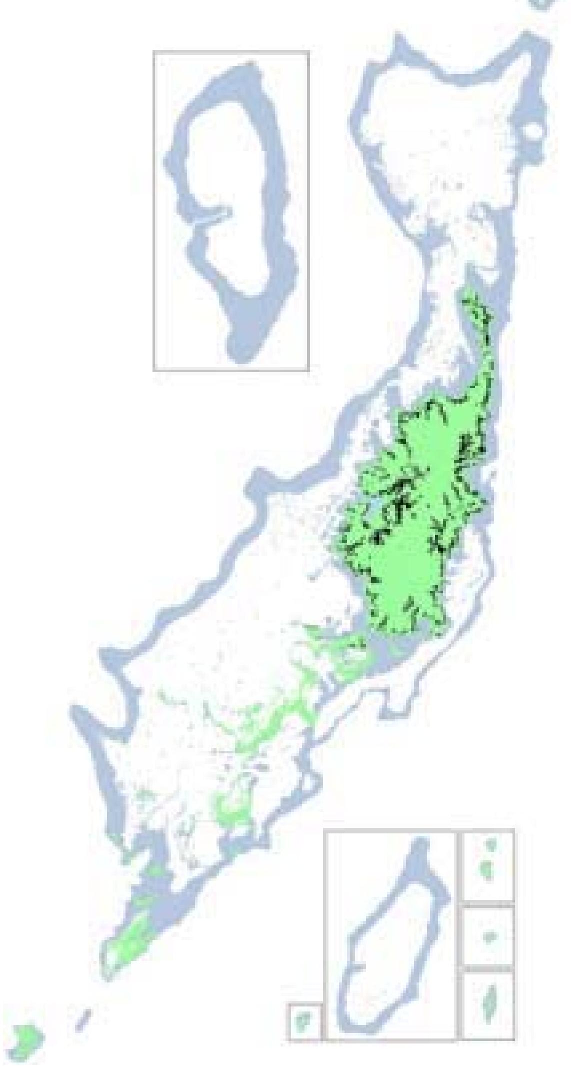
22. Volcanic Soil Forest, (Degraded C)



23. Riverine Forest



24. Swamp Forest

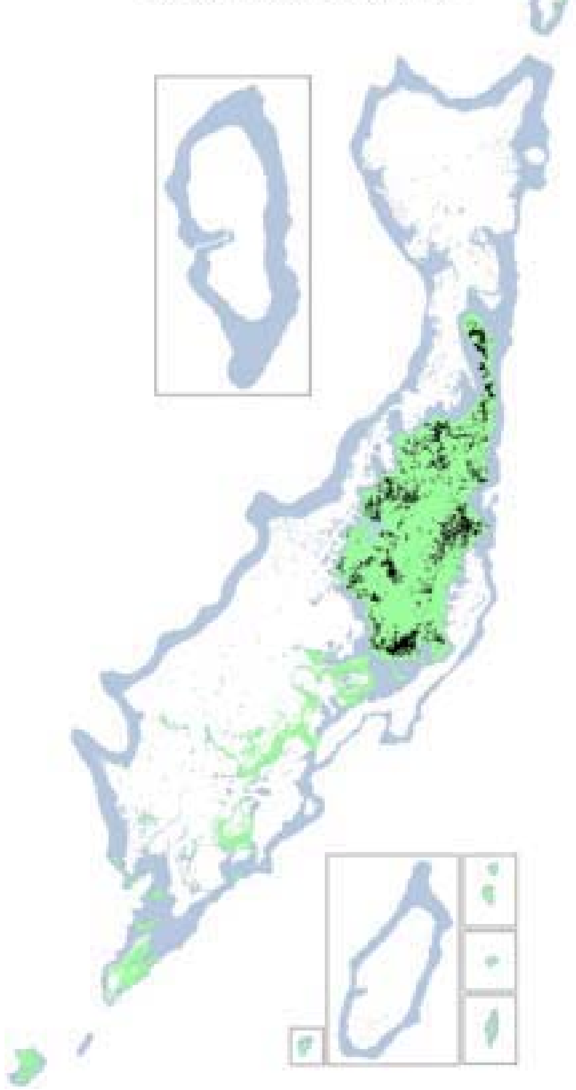


25. Atoll Forest

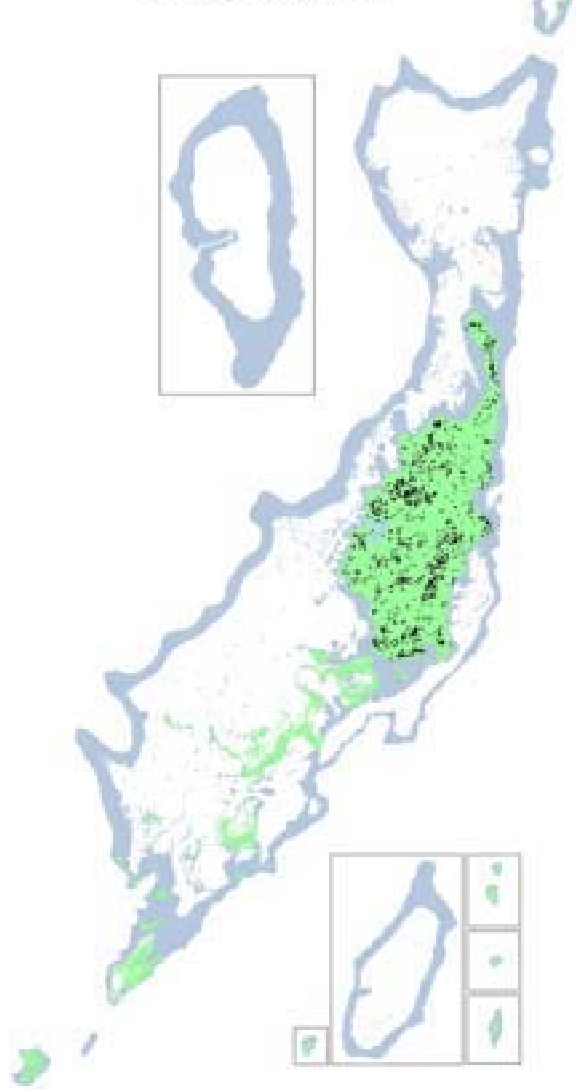
26. Limestone Forest
- Rock Islands

27. Limestone Forest
- Other Islands

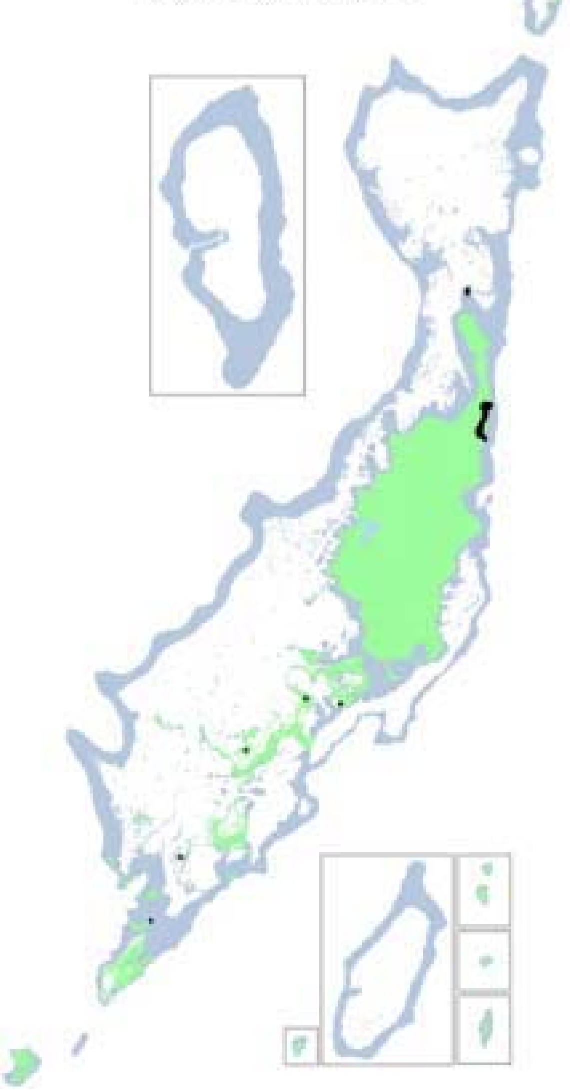
28. Savanna / Grasslands



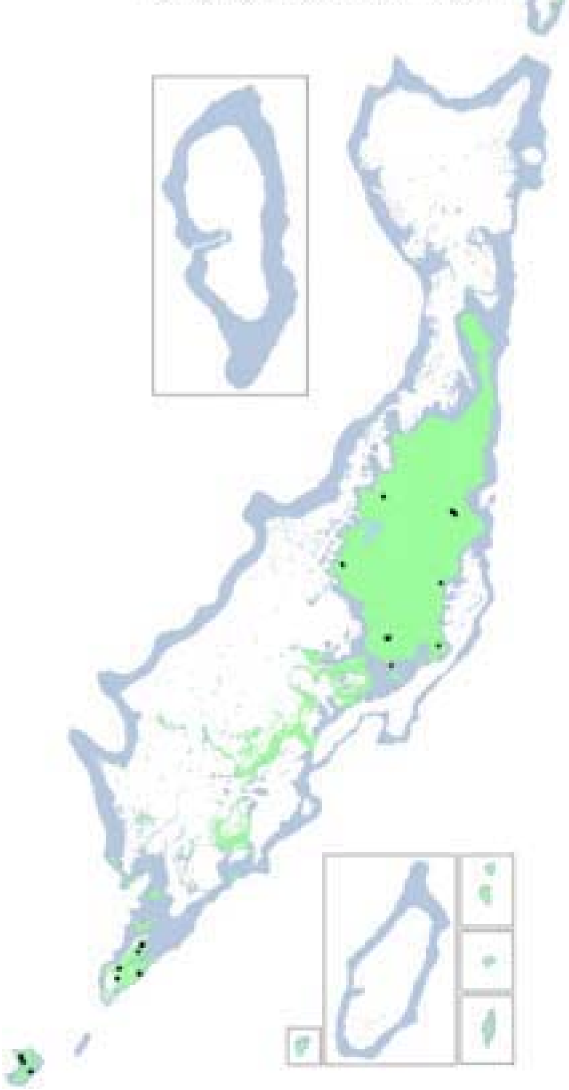
29. Scrub Savanna



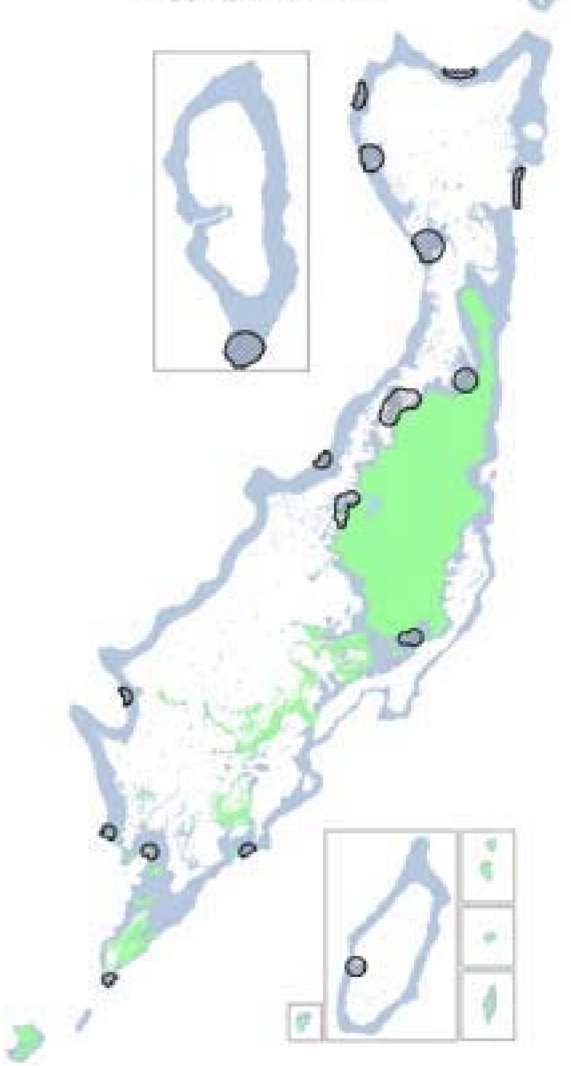
31. Lakes - freshwater



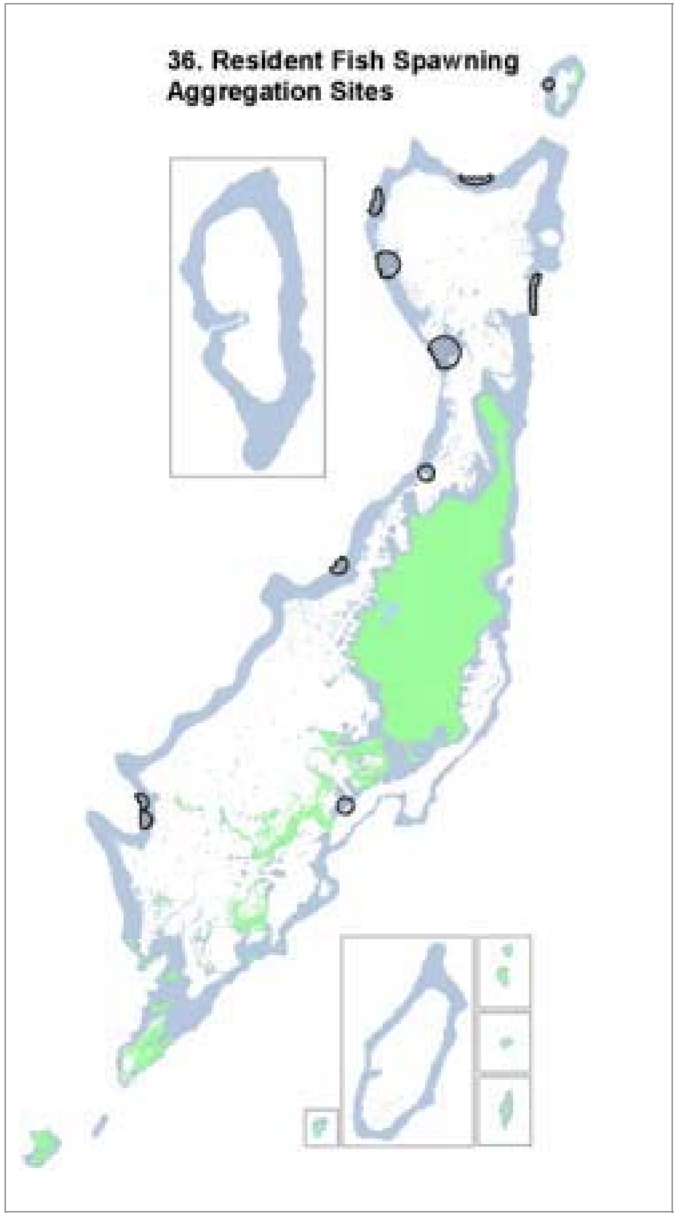
32. Freshwater Marsh



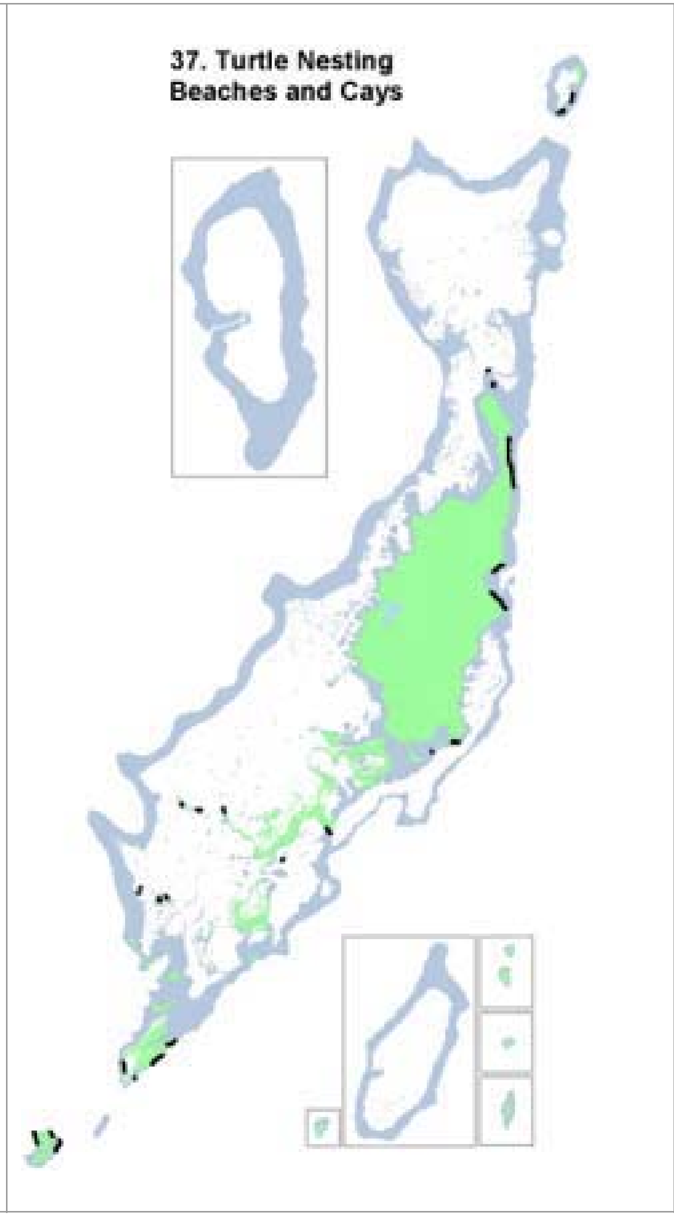
33. Other Freshwater Pools



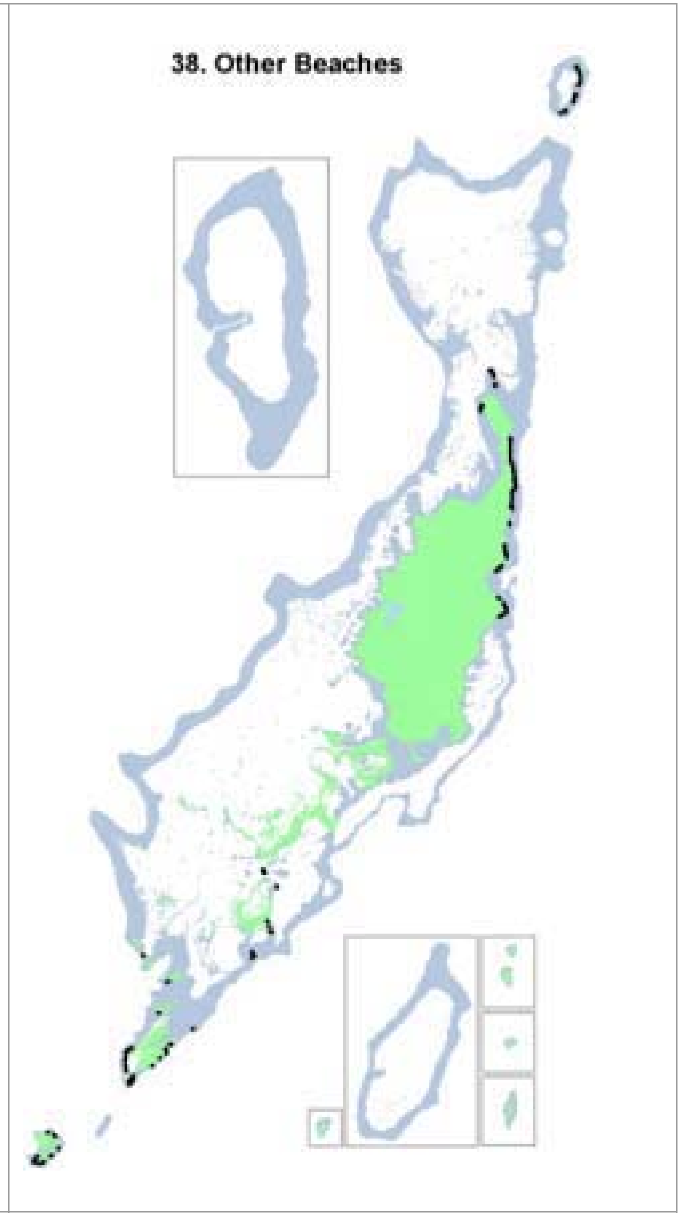
35. Transient Fish Spawning Aggregation Sites



36. Resident Fish Spawning Aggregation Sites

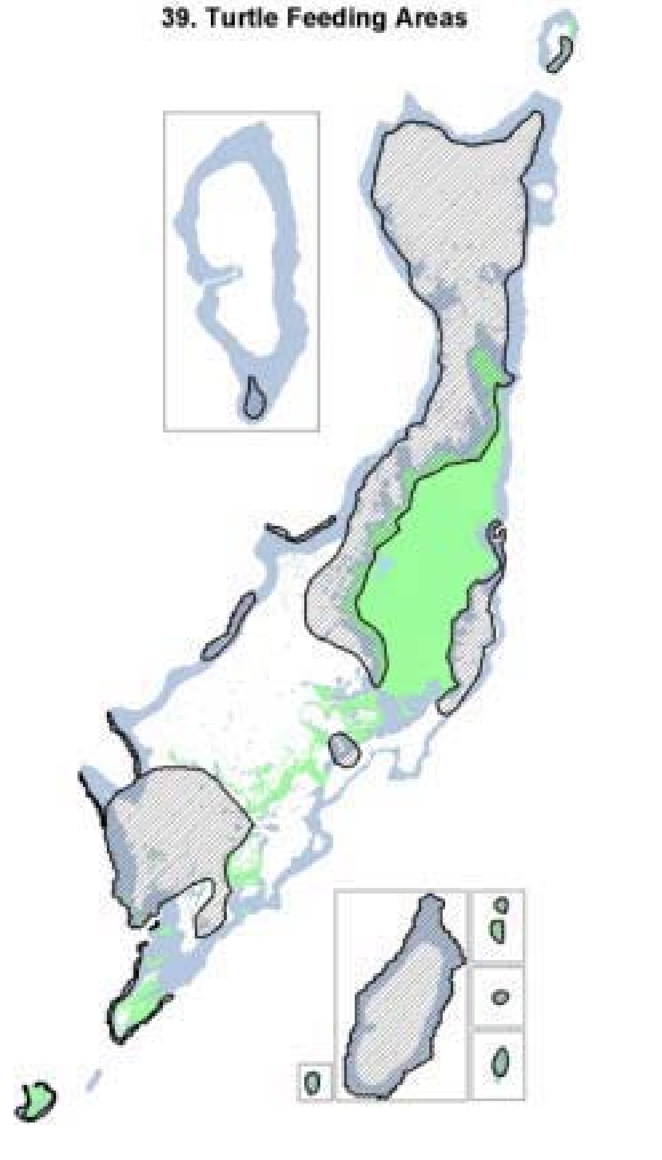


37. Turtle Nesting Beaches and Cays

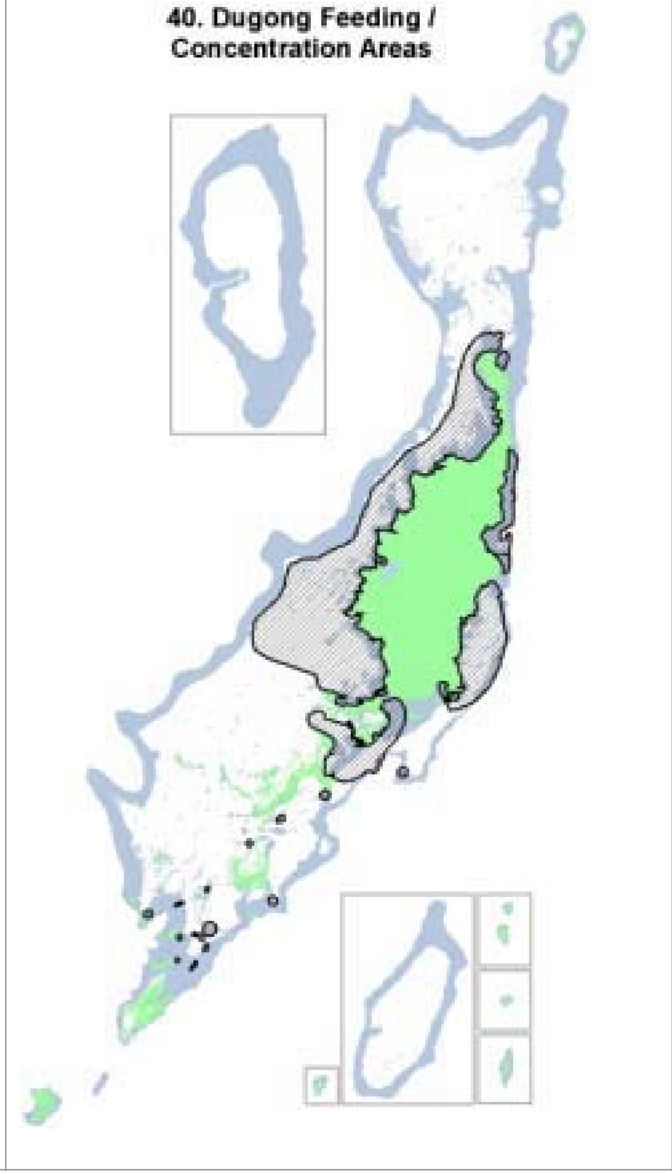


38. Other Beaches

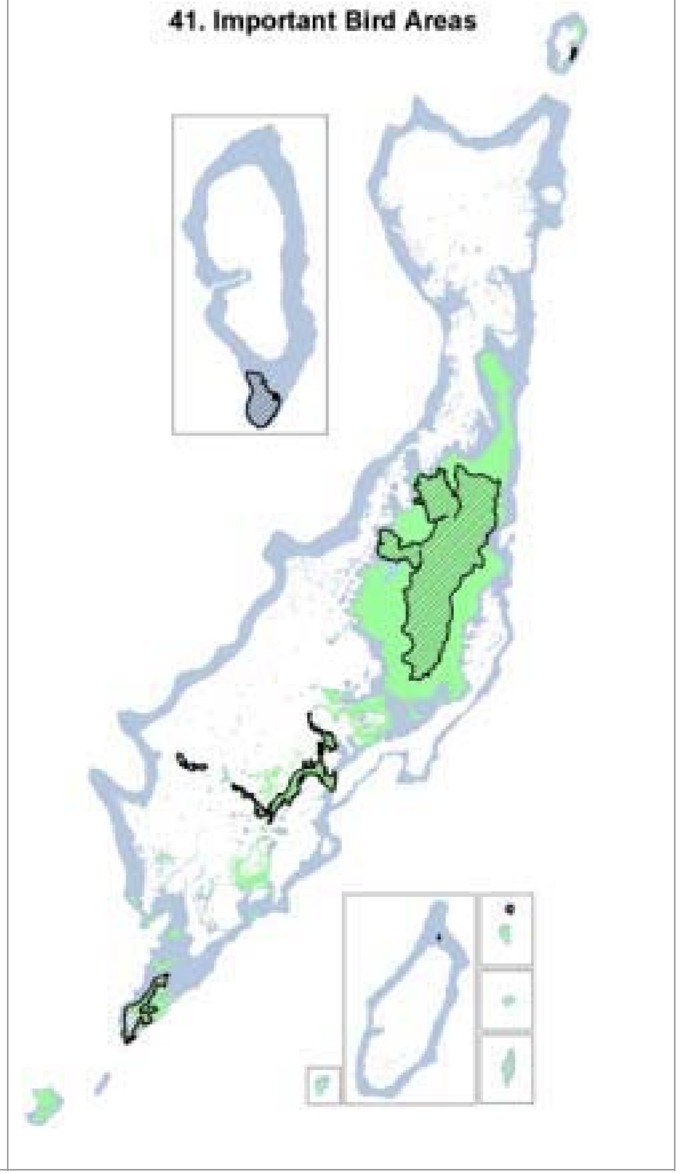
39. Turtle Feeding Areas



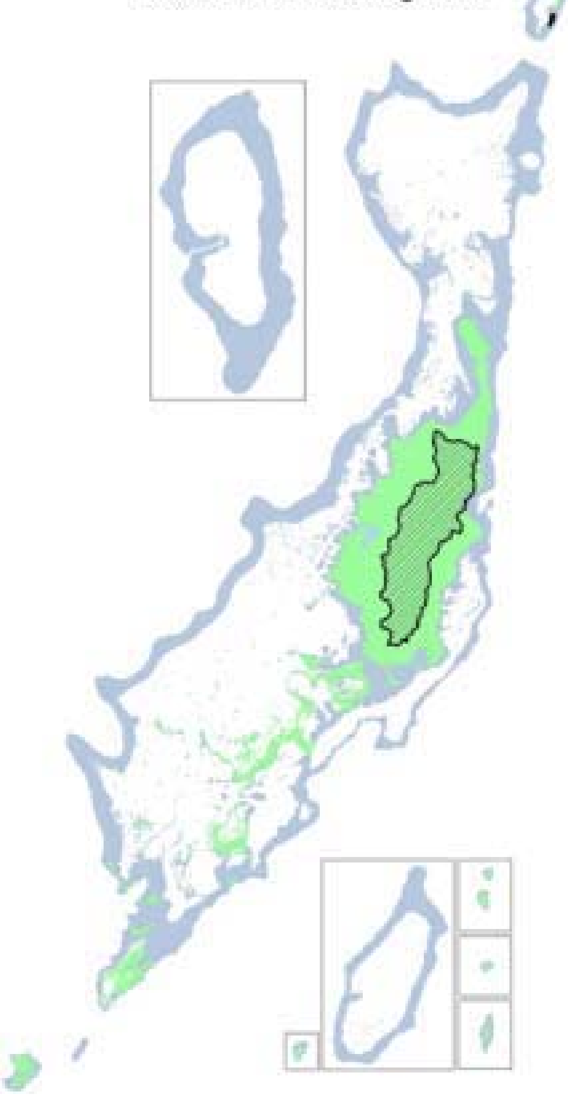
40. Dugong Feeding / Concentration Areas



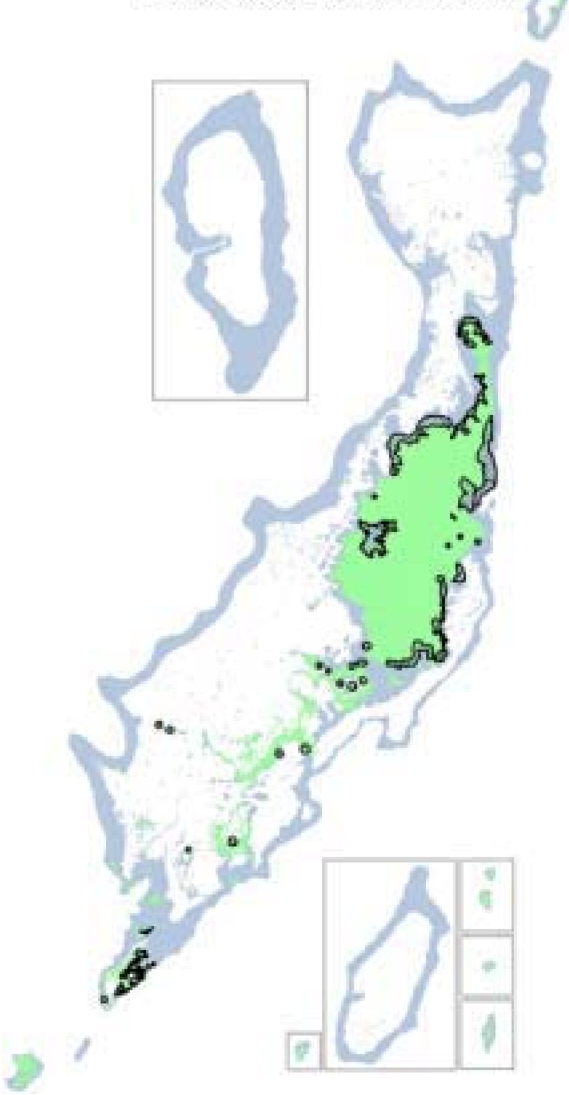
41. Important Bird Areas



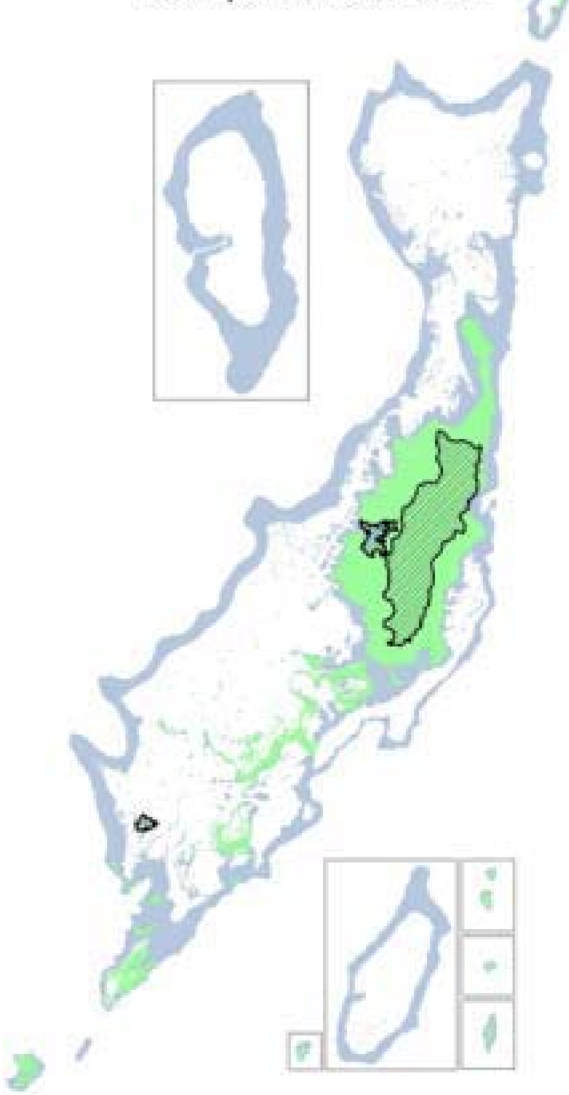
42. Fruit Bat roosting areas



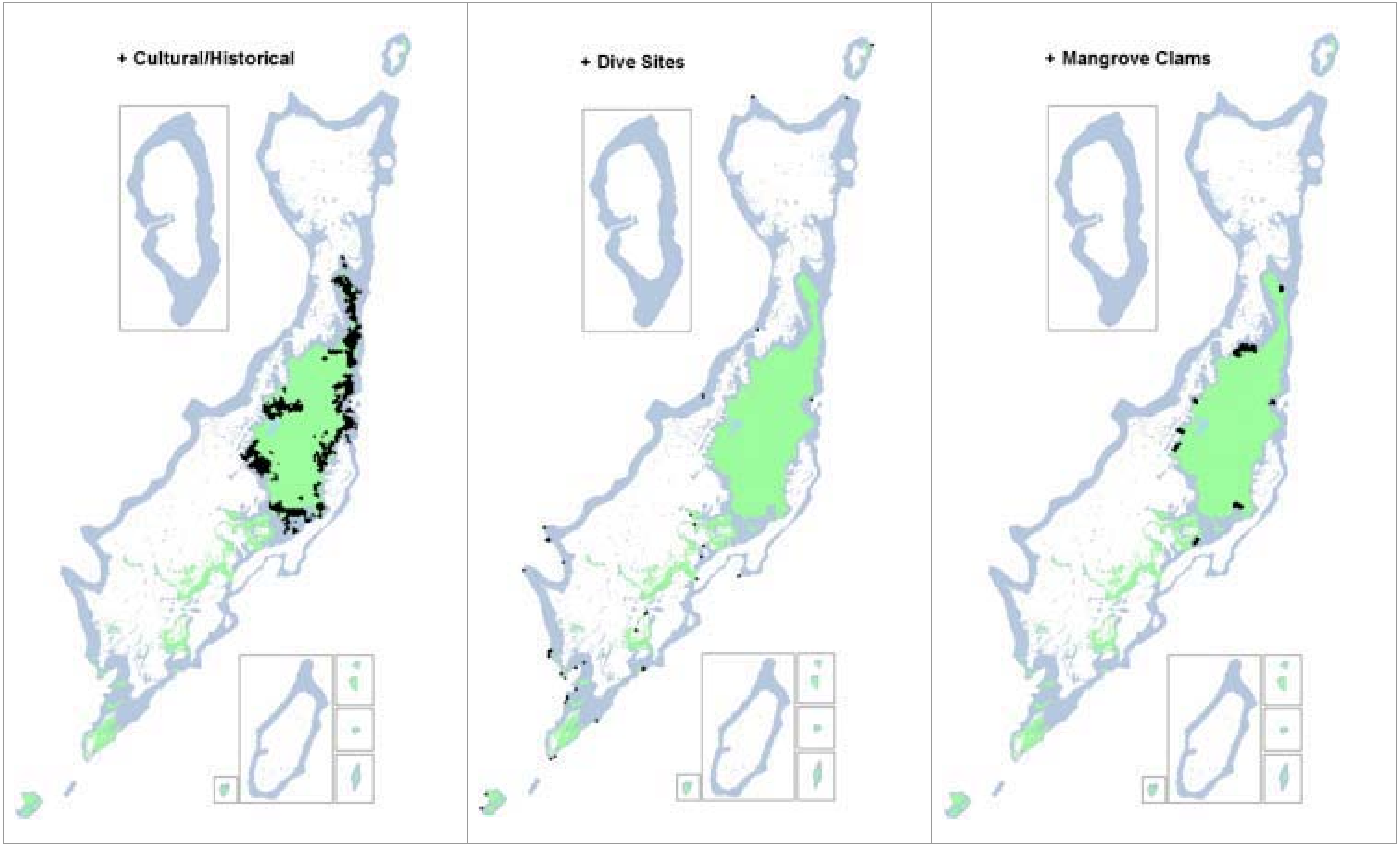
44. Crocodile Critical Habitat

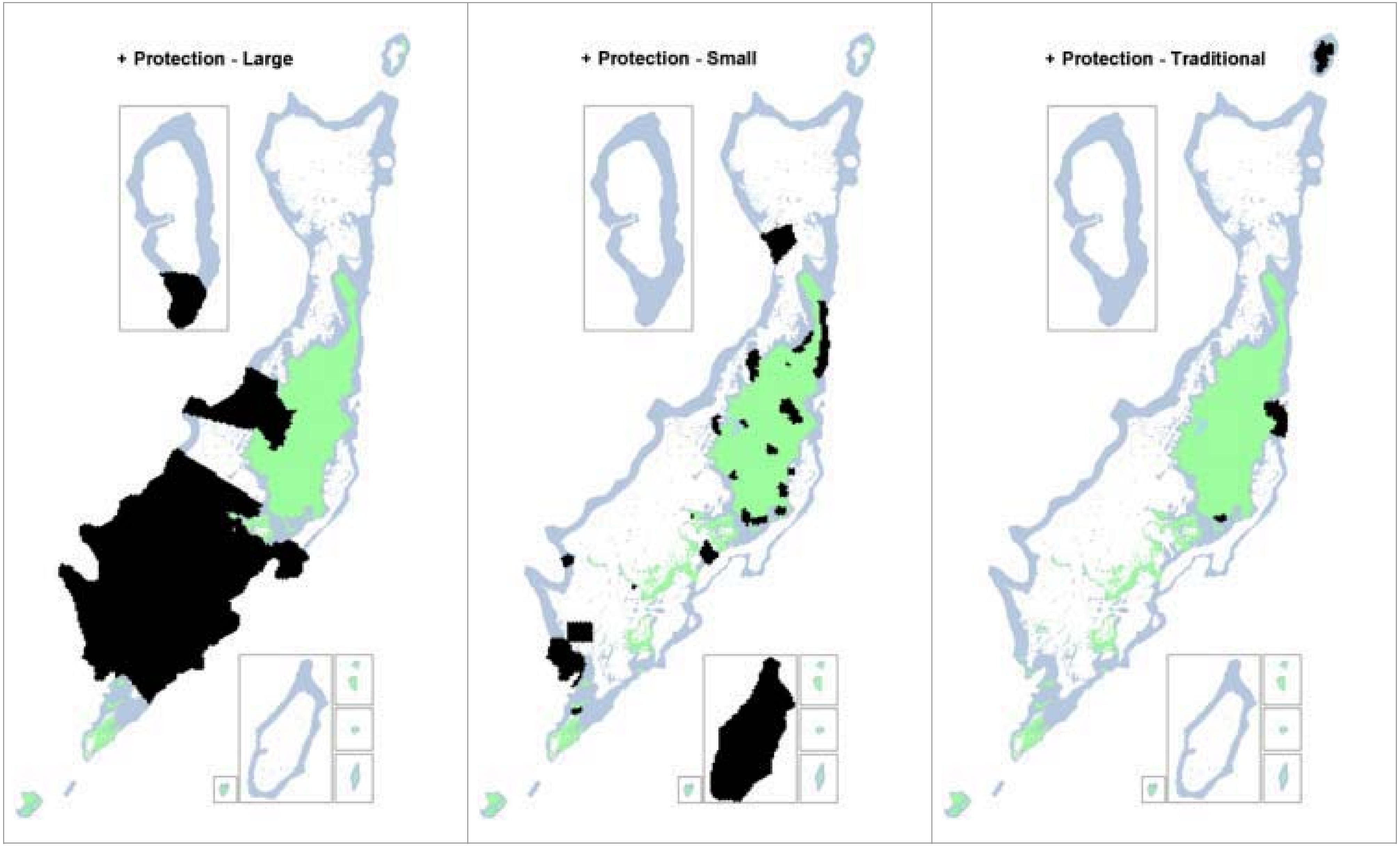


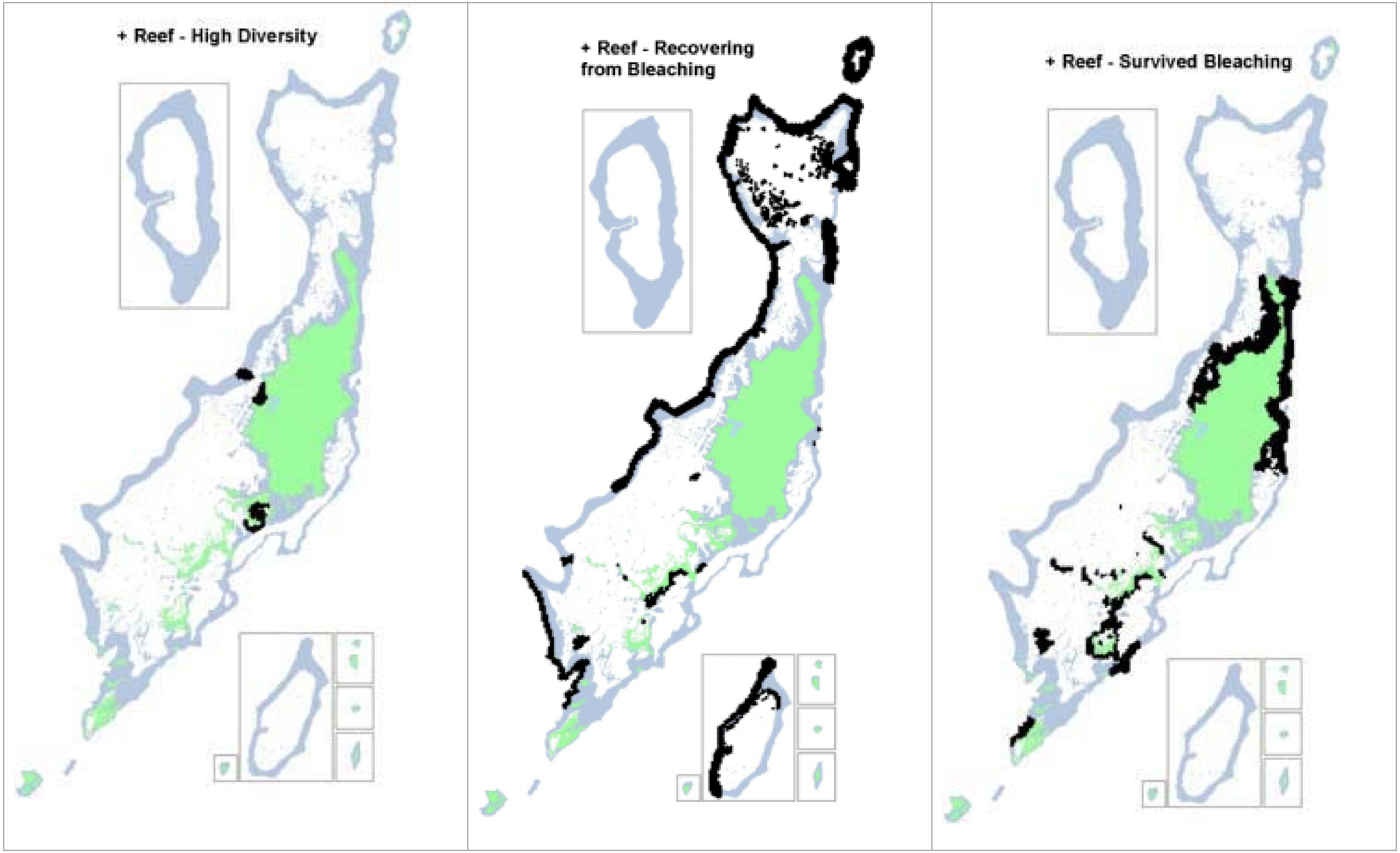
45. Important Insect Areas

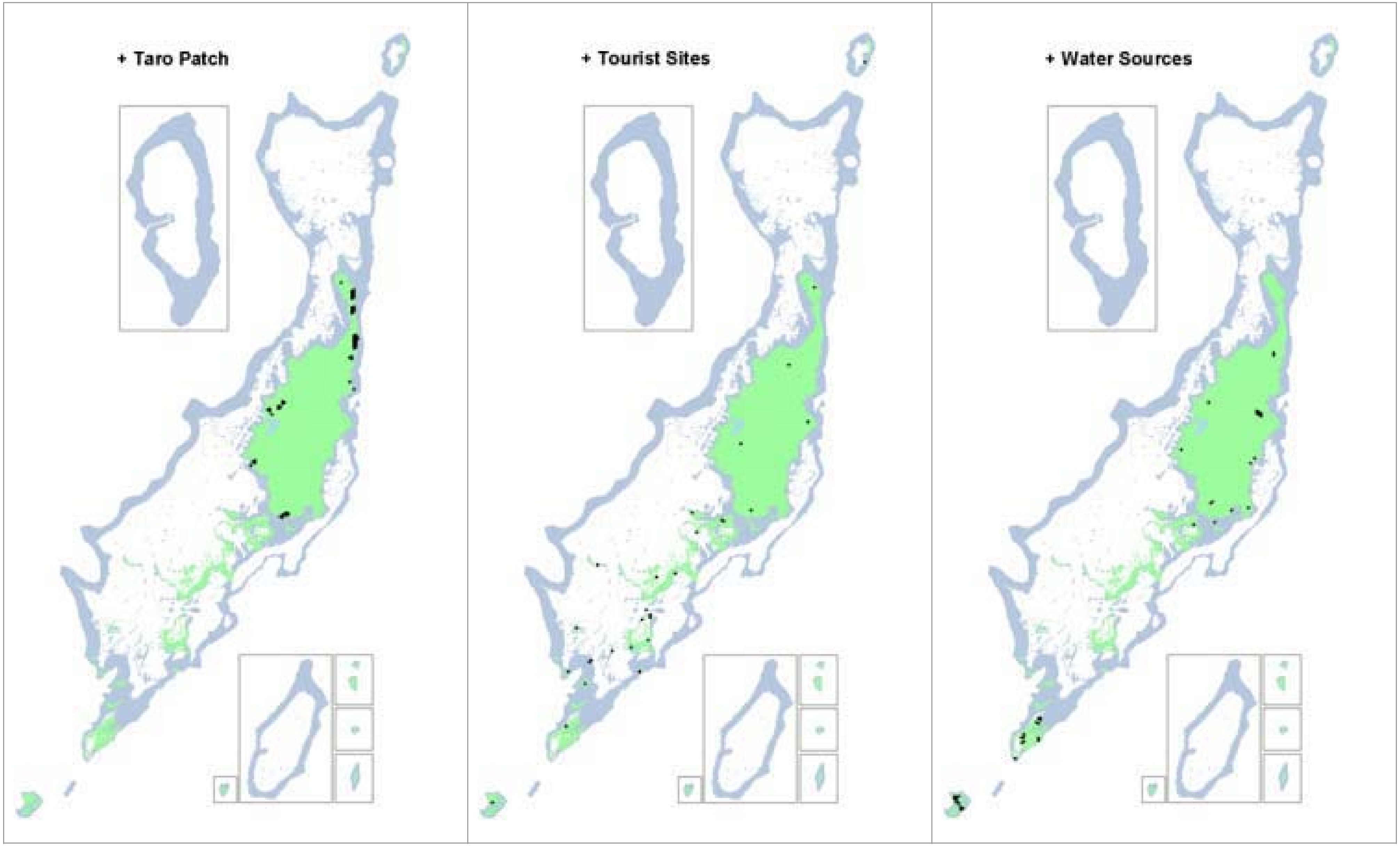


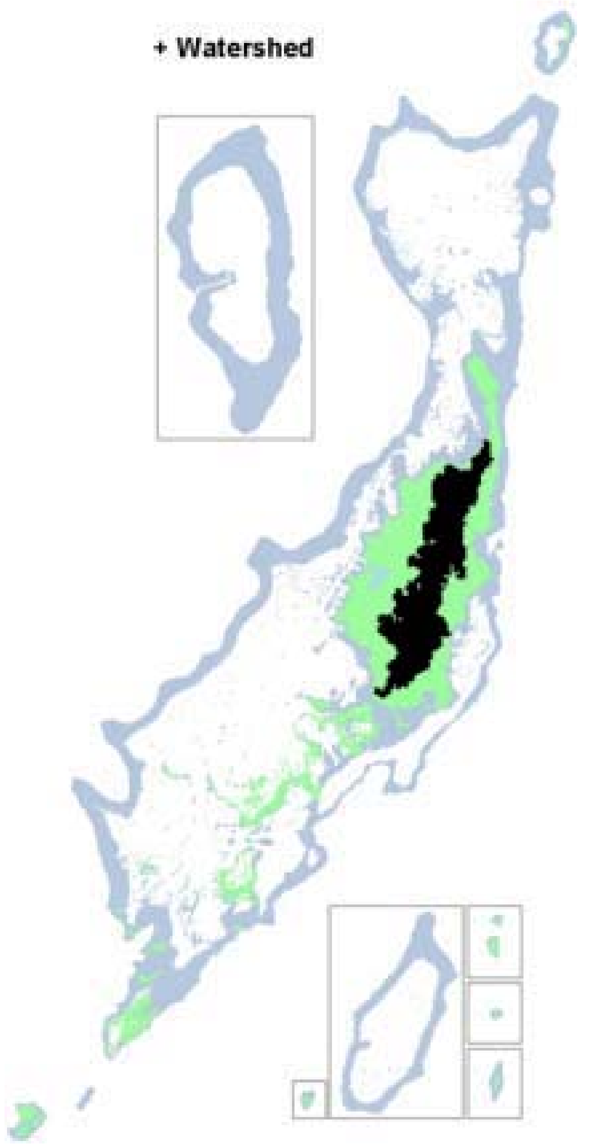
Appendix 8. Cost Surface GIS Layers

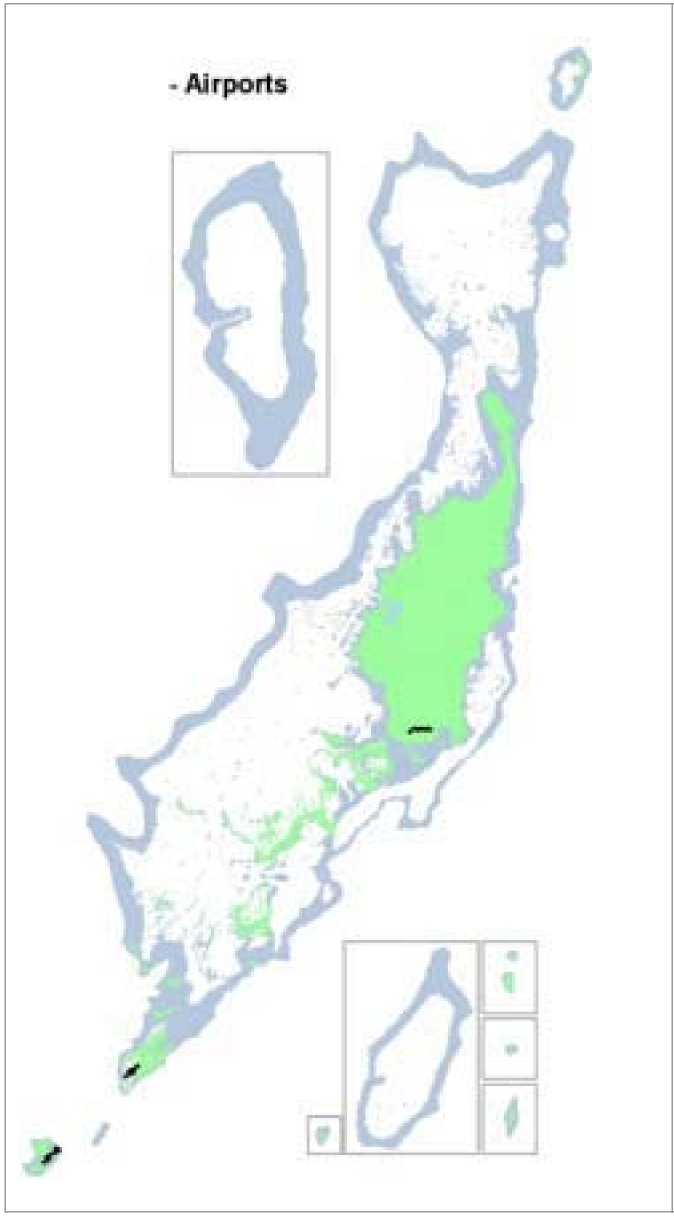


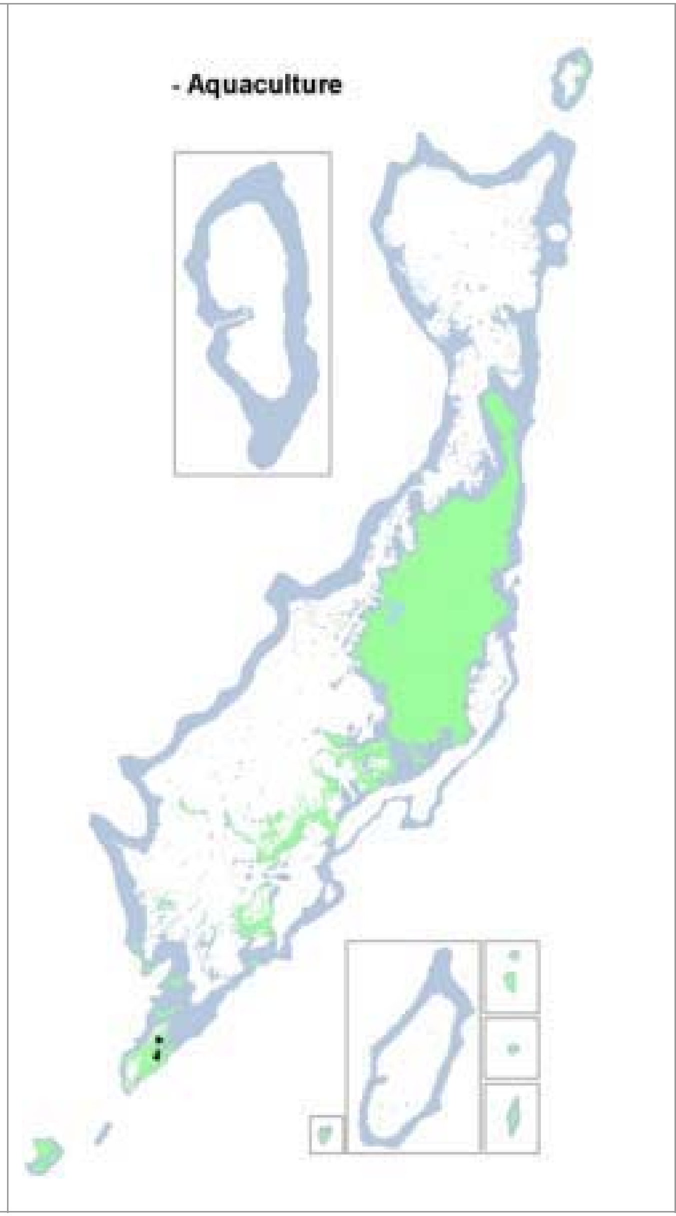

+ Protection - Large
+ Protection - Small
+ Protection - Traditional

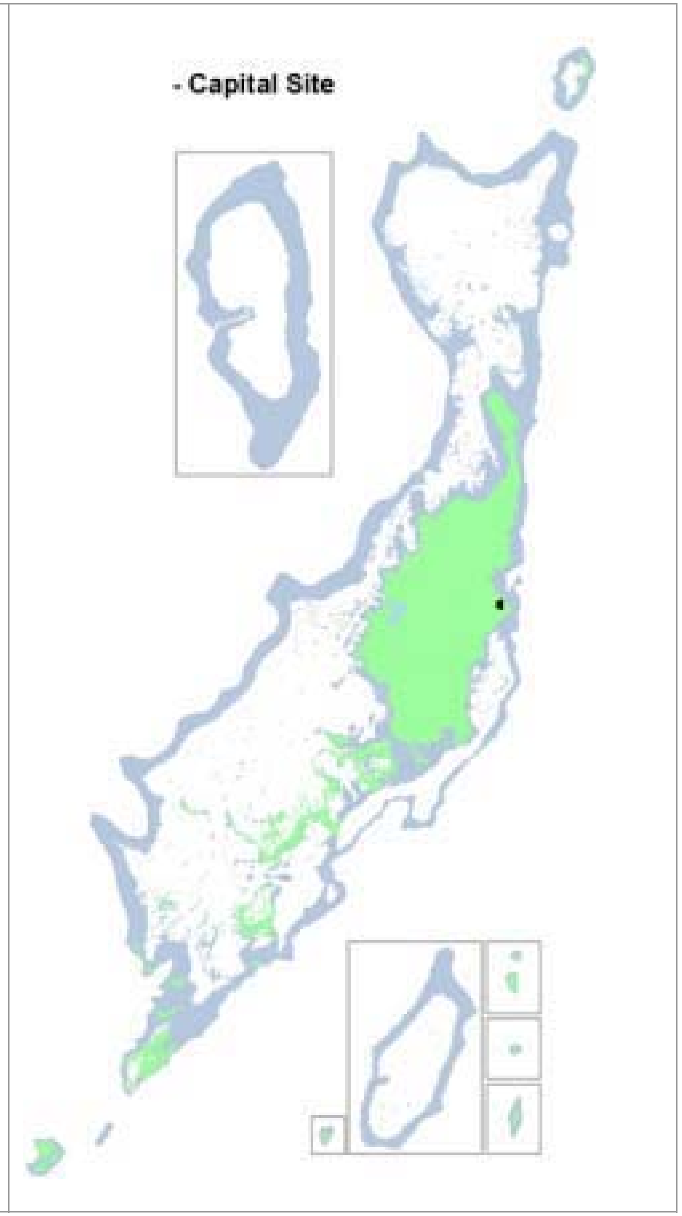

+ Reef - High Diversity
+ Reef - Recovering from Bleaching
+ Reef - Survived Bleaching

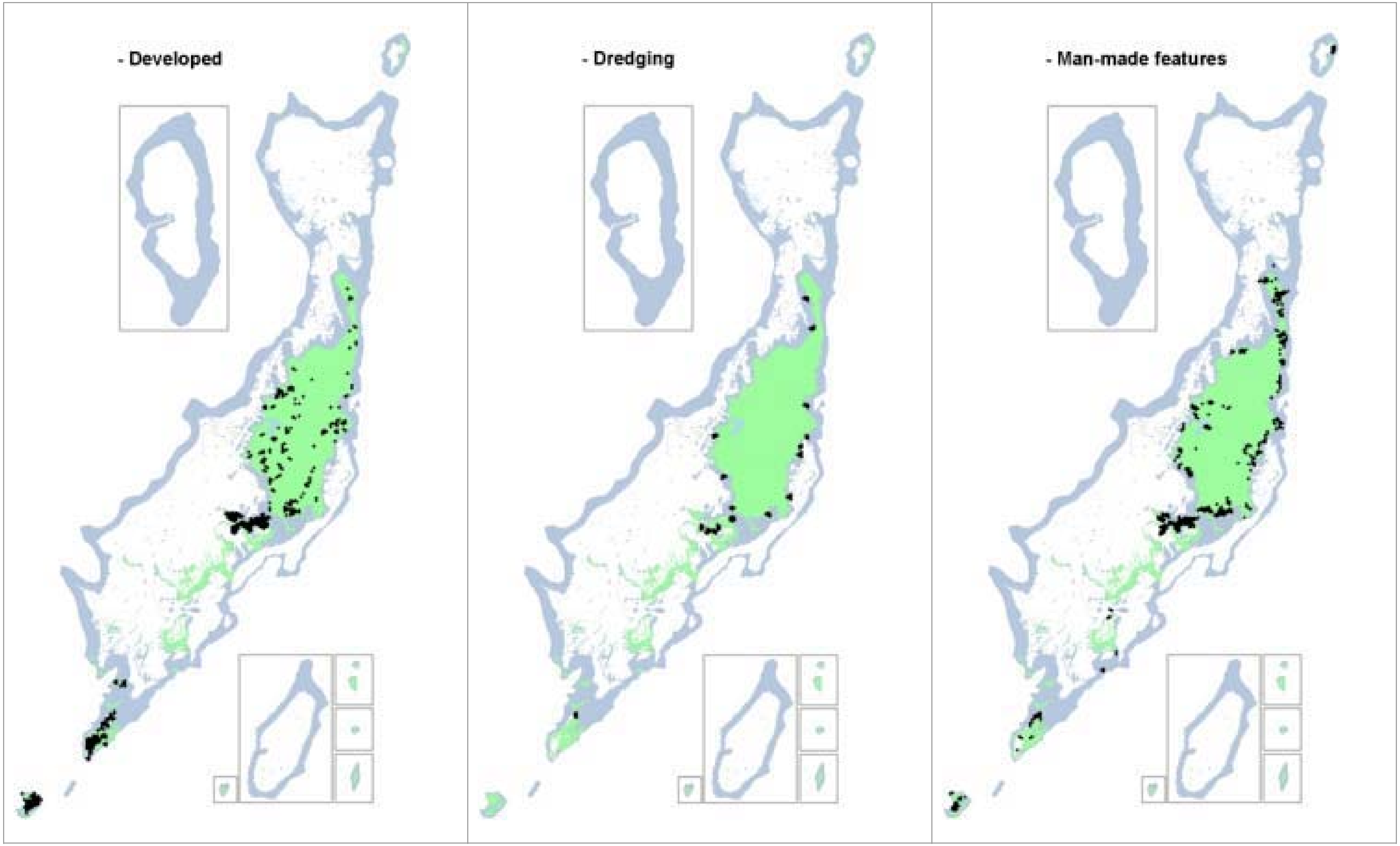

+ Taro Patch
+ Tourist Sites
+ Water Sources

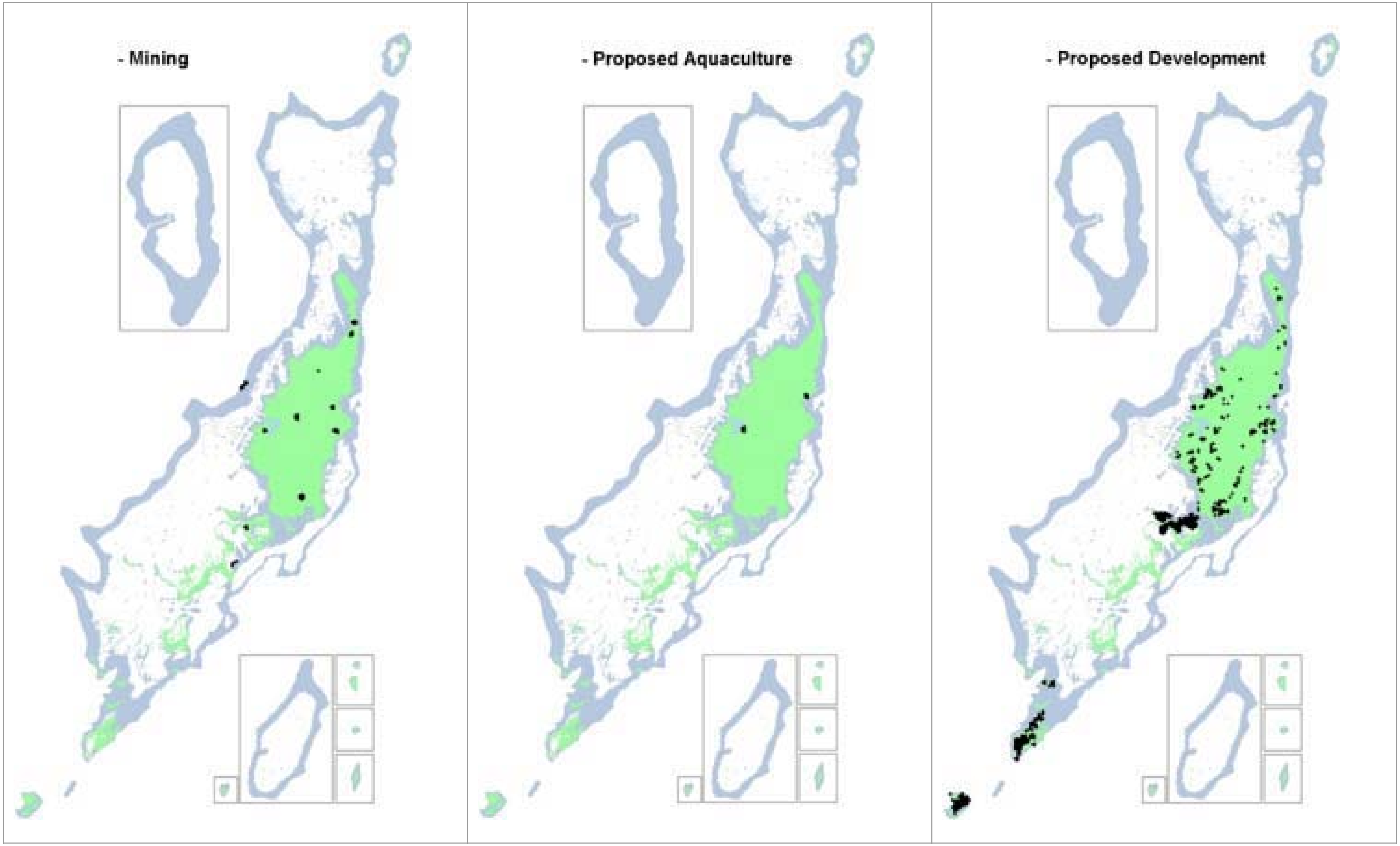

+ Watershed

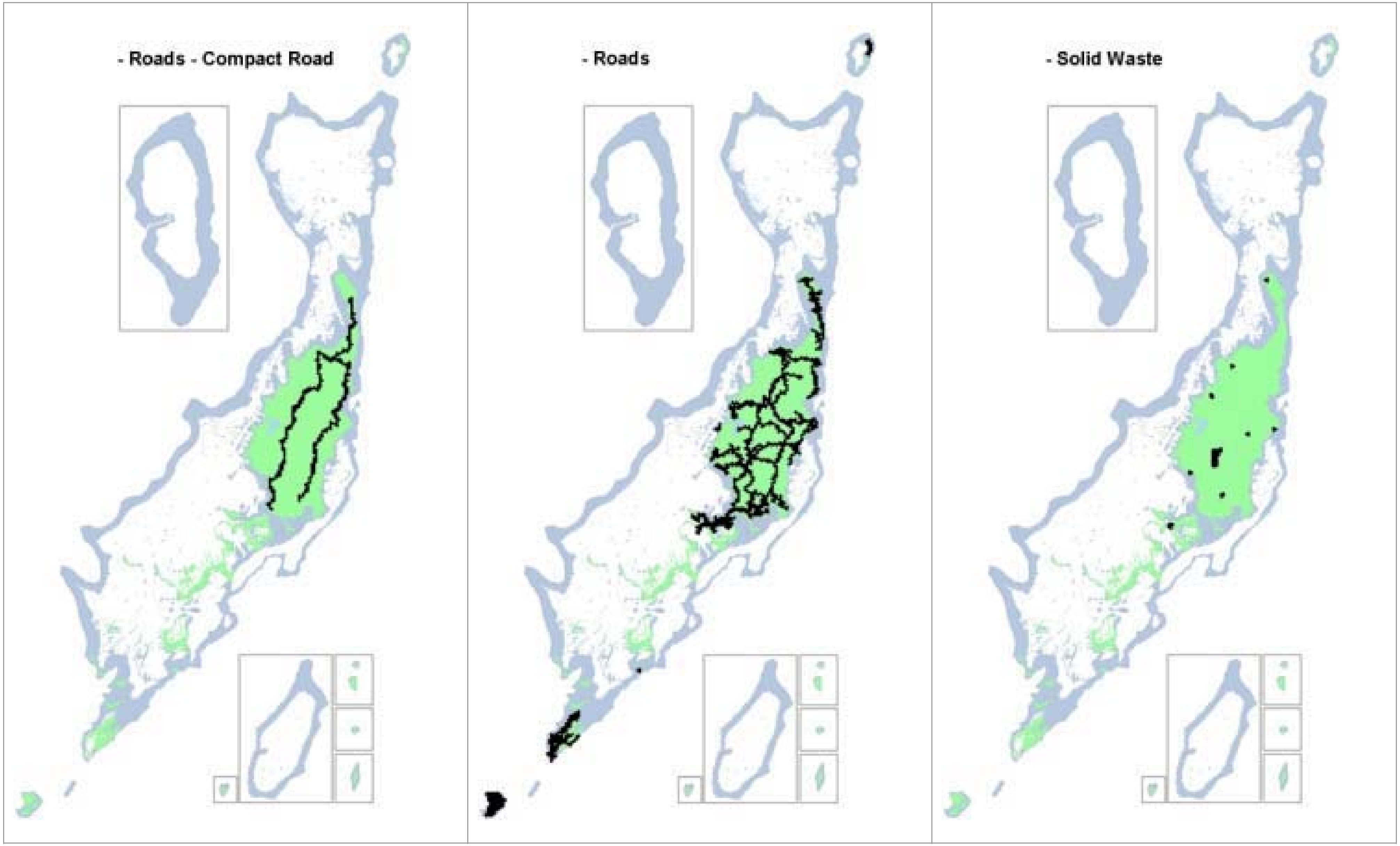

- Airports


- Aquaculture


- Capital Site


- Developed
- Dredging
- Man-made features


- Mining
- Proposed Aquaculture
- Proposed Development


- Roads - Compact Road
- Roads
- Solid Waste

The mission of The Nature Conservancy is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.

The Conservancy's Pacific Island Countries program supports marine and terrestrial conservation projects in Melanesia and Micronesia including Papua New Guinea, the Solomon Islands, Palau and the Federated States of Micronesia.

The Nature Conservancy

SAVING THE LAST GREAT PLACES ON EARTH

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