SPATIAL ANALYSIS IN SUPPORT OF DEVELOPMENT OF THE KOSRAE PROTECTED AREA NETWORK

Technical report prepared for The Nature Conservancy

April 2019

Spatial analysis in support of development of the Kosrae Protected Area Network. Technical report prepared for The Nature Conservancy, March 2019.

Authors: Rebecca Weeks*

*Corresponding author email: rebecca.weeks@jcu.edu.au

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Executive Summary

Though Kosrae has few existing protected areas (PAs), new conservation areas have been proposed in all four municipalities. It is thus timely to consider how well the existing and proposed PAs might work together as a protected area network (PAN) to achieve regional conservation goals, and whether the design of proposed PAs is adequate to achieve local management objectives.

This report presents methods and results of the following spatial analyses to inform recommendations for improving the design of Kosrae's PAN:

1. A gap analysis of Kosrae's existing protected area network, with respect to representation targets specified by the Micronesia challenge and in terms of adequacy for protecting key fish species;
2. Spatial conservation prioritization to identify indicative priority areas for conservation.

The outputs from these analyses may be used by The Nature Conservancy (TNC), Kosrae Conservation & Safety Organization (KCSO), and other state-level actors to assess progress towards state- and regional-level objectives for the Kosrae PAN, and to refine the design of existing and proposed PAs. Outputs, particularly the MPA Scorecards may also be shared with communities to support planning processes regarding the location and boundaries of individual PAs.

An overarching challenge to spatial conservation in Kosrae is the small extent of marine and terrestrial habitats within the State. This constrains opportunities to designate PAs that restrict access to natural resources, and imposes constraints on the size of PAs (and marine protected areas in particular, given the high level of dependence upon reef fisheries) that can be designated.

At present, less than 0.1% of Kosrae's nearshore marine area and 8% of it's terrestrial area are protected within the PAN; however, this will increase to 16% of marine area and 29% of terrestrial area protected if the currently proposed protected areas are designated. This represents good progress towards achieving Micronesia Challenge targets. Where opportunities exist to review and potentially revise the boundaries of proposed PAs prior to designation, consideration should be given to whether they could be moved or expanded to include areas of currently underrepresented habitat types: notably blue holes, passes and coral reef areas of the exposed reef system, seagrass areas of the coastal barrier reef system, and mangroves.

Most of the existing and proposed marine protected areas (MPAs) are small, and thus only species with very small home ranges are likely to be adequately protected. Communities should carefully consider whether the design of their MPAs is likely to benefit the species that they care about most; information and visual tools provided in this report are designed to assist with those discussions. Improving protection for reef fish species with larger home ranges will require either making some MPAs larger, or alternative management strategies for those species (e.g. size limits, gear restrictions, or seasonal catch and/or sale bans).

The spatial conservation prioritization results presented here indicate priority areas where new conservation areas might be established to fill representation gaps in Kosrae's PAN. However, it is important to note that proposed protected areas indicate some level of existing community willingness to undertake conservation or management actions, and this is often more important than meeting representation targets or finding a protected area network with the lowest possible "cost".

Given Kosrae's small area, it is unlikely to be feasible to add further protected areas to Kosrae's PAN, beyond those that have already been proposed. This emphasises the need to ensure that PAs are well-designed (i.e. to achieve specific local objectives) and highlights a clear role for alternative and complementary management strategies (including non-spatial management) to help achieve conservation objectives.

Introduction

Background and context for a Kosrae State protected area network

Kosrae is the easternmost of the four constituent states of the Federated States of Micronesia (FSM), located around 600 km north of the equator, approximately midway between Guam and Hawaii. Kosrae is a single high island with a land area of 11,000 ha and a maximum elevation of 629 m. The island is covered by forested watersheds, bordered by extensive mangroves that cover approximately 15% of the land area. Fringing coral reefs surround the island and vary in width from <100 m on the southern and eastern shores to 1.6 km wide on the western coasts.

Although Kosrae has a small population (c. 6,000), Kosraeans are heavily dependent upon their natural resources, with subsistence farming and fishing remaining important to many families. A growing population, combined with a shift from a subsistence lifestyle to a cash economy (and a declining per capita income) are placing increasing pressures on the environment, and the coastal marine area in particular. Human density per coral reef area (130 individuals per km^2 reef) is approximately six times higher than the FSM average, and subsistence and artisanal fishing are critical for nutrition, informal employment and their contribution to the cultural identity of Kosraean communities.

Land ownership and tenure varies from state to state within FSM. In Kosrae, traditional ownership of resources is no longer recognised, and responsibility for protected area designation lies with the State. Kosrae State passed a Protected Areas Act in 2010, and in 2012 the State legally recognized the Utwe Biosphere Reserve in State Law 10-48. In 2014, the Yela Watershed was protected by a conservation easement, the first such agreement in the Pacific region. New marine protected areas have been proposed in all four municipalities (Figure 1), and terrestrial conservation areas have been proposed for the Olum and Mahkontowe watersheds. **It is thus timely to consider how well the existing and proposed protected areas might work together as a Protected Area Network to achieve regional conservation goals, and whether the design of proposed conservation areas is adequate to achieve local management objectives.**

Earlier conservation planning efforts (the FSM Blueprint, 2003) identified "Areas of Biodiversity Significance" and "Priority Action Areas" for conservation within the FSM. However, the areas identified for Kosrae covered a large proportion of the total marine and terrestrial extent of the State, and are thus impracticable as areas within which to focus conservation actions. More recently, The Nature Conservancy Micronesia (TNC) and partners have conducted conservation planning initiatives within each FSM State. These efforts have sought to balance a need for ecoregional planning and to make progress towards international and regional targets for biodiversity conservation (e.g. the Micronesia Challenge) with local (i.e. state-level) objectives for natural resource use, management and conservation. These planning processes have been completed for Pohnpei (2015), Yap (2016), and Chuuk (2017); this report contributes towards similar efforts being undertaken in Kosrae.

In February 2019, TNC and the Kosrae Conservation & Safety Organisation (KCSO) convened a Protected Area Network Design workshop in Tofol, Kosrae. Over two days, facilitators presented information on the principles and best practices of protected area network design, and participants identified local objectives for a protected area network and discussed how protected area design principles should and could be applied in Kosrae. Information emerging from that workshop forms the basis of the analyses presented here.

Local conservation objectives

Locally important habitats, species, special and unique features were identified by participants at the February 2019 PAN workshop (see Table 3 for a complete list). Marine features of importance included the coral reefs, seagrass, lagoon and blue hole habitats that provide for populations of food fish species (see Table 3) and exploited marine invertebrates. Terrestrial features included upland watersheds, rivers, and streams that support agroforestry and healthy downstream habitats, and the unique Terminalia (or ka) forests.

Key threats and challenges to resource management were also identified (see Table 3). These included overharvesting of resources (e.g. marine and mangrove species), pollution from fishing vessels and poor land use practices (e.g. pig pens adjacent to freshwater), and upland development, land clearing for which has caused erosion and sedimentation downstream. Poaching was noted as a problem within existing protected areas, despite benefits from conservation actions having been observed.

Participants at the February 2019 Protected Area Network Planning Workshop

Gap analysis of Kosrae's existing marine and terrestrial protected area network

At its simplest, a gap analysis is an assessment of the extent to which a protected area system meets conservation objectives. The "gaps" are the difference between where the protected area network is now, and where we would like it to be. Gap analysis considers three different types of "gaps" in the protected area network:

Representation gaps: either no representation of a particular species or habitat type in any protected area, or not enough examples of the species or habitat are represented to ensure long-term protection.

Ecological gaps: while the species or habitat type occurs in the protected area system, occurrence is either of inadequate ecological condition, or the protected area(s) fail to address species' movements or specific ecological conditions needed for long-term survival or ecosystem functioning.

Management gaps: protected areas exist but management regimes (management objectives, governance types, or management effectiveness) do not provide full security for particular species or ecosystems given local conditions (e.g. poaching might be occurring).

Representation gaps

Analysis of representation gaps in a protected area system requires information on the boundaries and extent of existing protected areas, a set of conservation features to be considered for representation within the protected area network, and quantitative representation targets.

Existing protected areas

During the February 2019 PAN workshop, participants delineated boundaries of existing and proposed protected areas in Kosrae State. These are shown in Figure 1.

Conservation features

Marine habitat information (Figure 2) was based on the Millennium Coral Reef Mapping Project data (IMaRS-USF & IRD, 2005). Coral reef classes on the coastal barrier reef system of Western Tafunsak are identified as distinct from those on the exposed reef system surrounding the rest of the island. Seagrass and mangrove habitats were identified during previous conservation planning exercises for Kosrae. Terrestrial habitat information (Figure 3) comprises vegetation and forest types from USGS surveys, also used in prior conservation planning for Kosrae.

Representation targets

In 2006, the political leaders of five nations in Micronesia (FSM, the Republic of the Marshall Islands, the Republic of Palau, Guam, and the Commonwealth of the Northern Marianas Islands) initiated a friendly challenge across jurisdictions to 'effectively conserve' at least 30% of their marine resources and 20% of terrestrial resources by 2020, known as "The Micronesia Challenge". This ambitious challenge far exceeds current goals set by international conventions and treaties; for example, the Aichi Biodiversity Targets set out by the Convention of Biological Diversity state that: "*by 2020, at least 17 per cent of terrestrial and inland water areas, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures*".

To ensure adequate and unbiased protection for different ecosystem and habitats types, representation targets should be applied to the different habitat types present (e.g. Figure 2, Figure 3), rather than to marine and terrestrial areas overall.

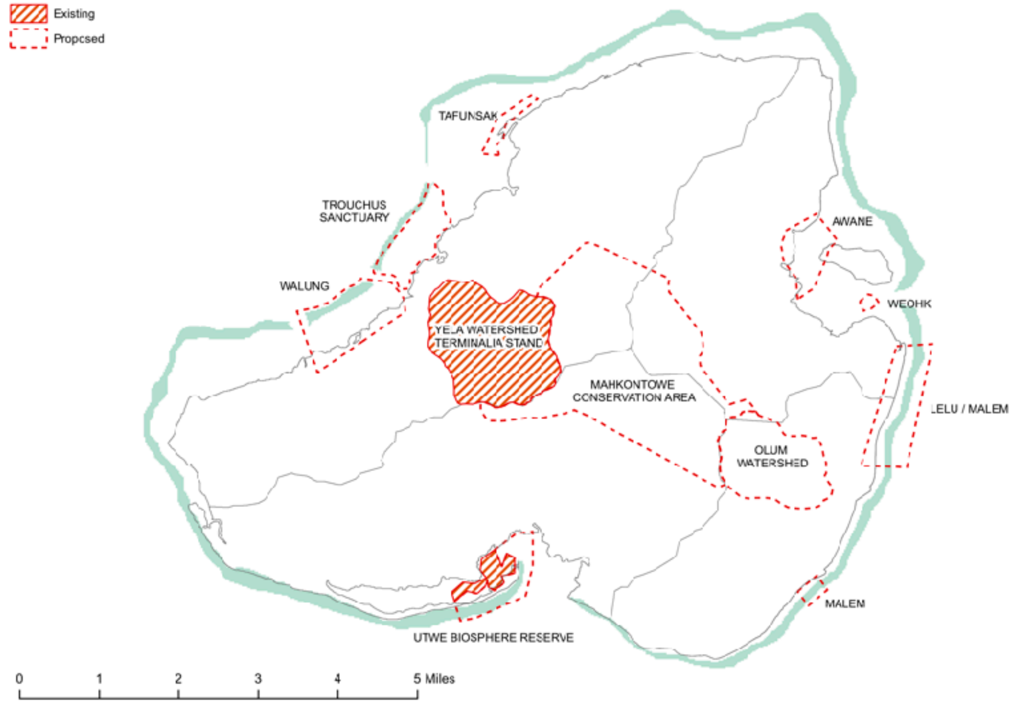


Figure 1. Existing and proposed protected areas in Kosrae State

Results

At present, less than 0.1% of Kosrae's near shore marine area and 8% of it's terrestrial area are protected within the PAN (Table 1 and Figure 4); however, this will increase to 16% of marine area and 29% of terrestrial area protected if the currently proposed protected areas (shown in Figure 1) are designated (Figure 5). This would bring Kosrae half way towards achieving the Micronesia Challenge target of protecting 30% of marine areas, and would exceed the target to protect 20% of terrestrial areas, which would be a significant achievement given the relatively small area of marine habitats within Kosrae State.

Kosrae would still have a lower percentage of marine areas protected than in Pohnpei and Yap (Figure 4). However, protected area extent should not be considered as a sole (or ultimately a reliable) indicator of conservation effectiveness, and some of Pohnpei's designated PAs are not yet well managed. If proposed protected areas are designated, Kosrae would have a greater level of protection for terrestrial habitats than either Pohnpei or Yap.

Given Kosrae's small habitat area, it is unlikely to be feasible to add further protected areas to Kosrae's PAN, beyond those that have already been proposed. However, the placement and design of proposed protected areas should consider how well different habitat types are represented within the PAN at present, as well as their adequacy for protecting key features (see below).

The extent to which individual habitat types are represented within the PAN is highly variable (Table 1 and Figure 5). Whilst the proposed MPA in Walung would do a good job at protecting most coral reef associated habitats in the coastal barrier reef system (though more protection may be required for seagrass habitats), forereef and reef flat habitats remain underrepresented in proposed MPAs on Kosrae's exposed reef system, and critical blue hole and pass habitats are entirely absent from the PAN. Increased protection for mangrove habitats is also warranted, given their relatively low representation within proposed PAs, and importance for locally important resources. Communities might be encouraged to consider whether modifications to the boundaries of proposed protected areas could be made to include some areas of these habitats. While freshwater marsh habitats are absent from the PAN, the small total extent (14 ha) of this habitat type should be noted.

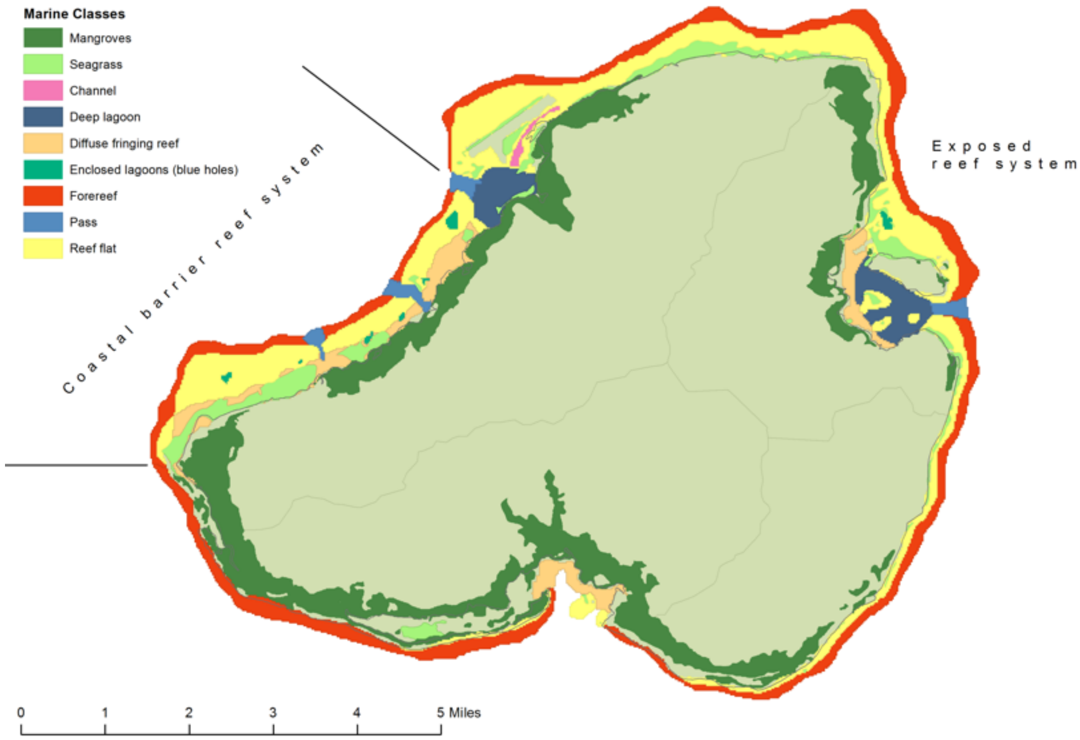


Figure 2. Marine habitat classes in Kosrae

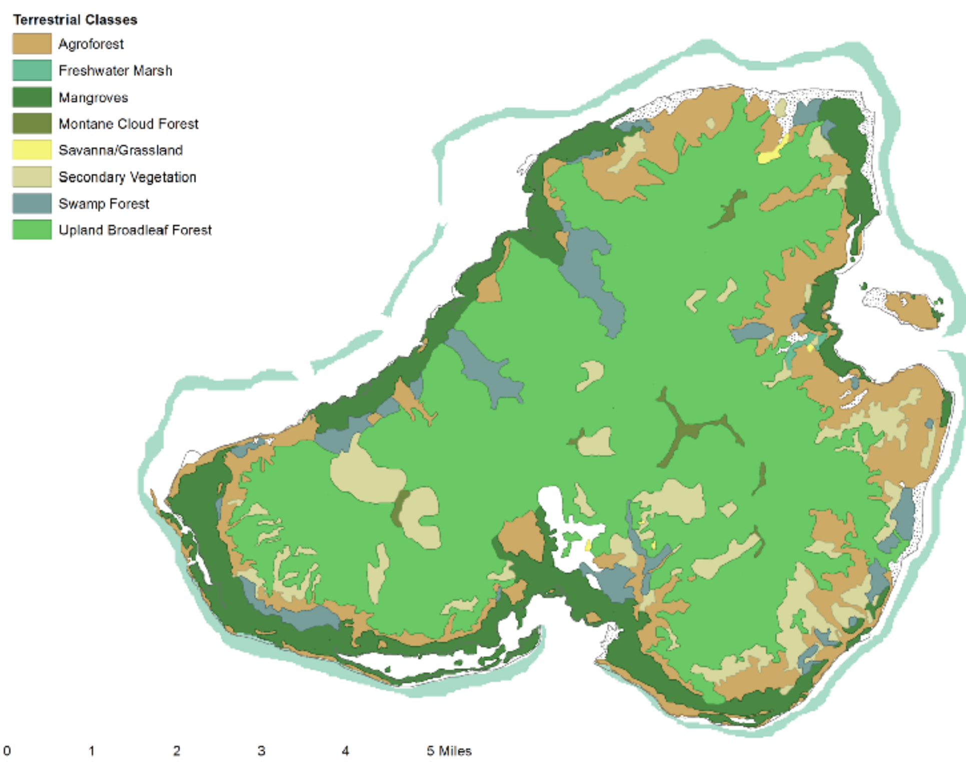


Figure 3. Terrestrial habitat classes in Kosrae

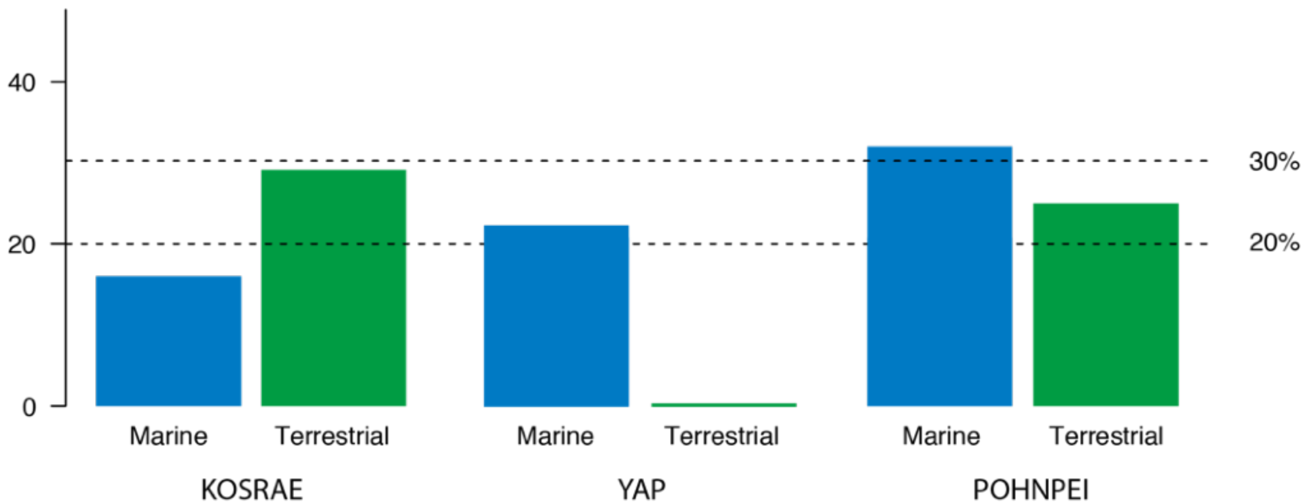


Figure 4. Progress towards Micronesia Challenge representation targets for marine and terrestrial habitats made by Kosrae (including proposed PAs), Yap and Pohnpei

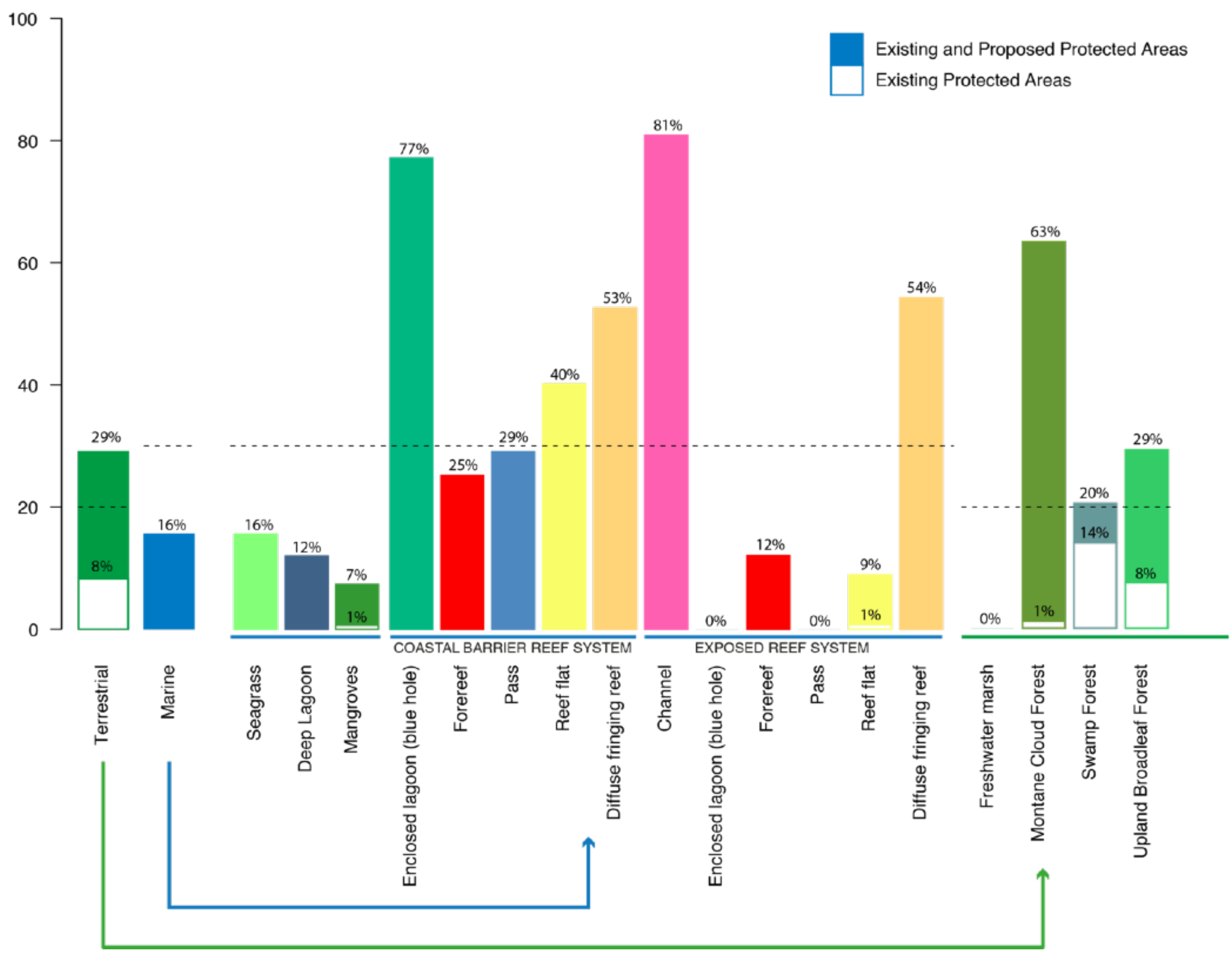


Figure 5. Representation gap analysis of marine and terrestrial habitat classes in Kosrae's protected area network

Table 1. Gap analysis of Yap's protected area network

Habitat Type	*Total Area (ha)*	*Representation Target*	*% protected in existing PAs*	*% protected in existing & proposed PAs*
Marine	**2814.81**	**30%**	**0%**	16%
Seagrass	340.05	30%	0%	16%
Deep Lagoon	196.84	30%	0%	12%
Mangroves	1459.49	30%	1%	7%
Coastal Barrier Reef System		30%	0%	40%
Enclosed lagoons (blue holes)	15.85	30%	0%	77%
Forereef	135.09	30%	0%	25%
Pass	53.71	30%	0%	29%
Reef flat	337.33	30%	0%	40%
Diffuse fringing reef	132.70	30%	0%	53%
Exposed Reef System		30%	0.4%	14%
Enclosed lagoons (blue holes)	4.98	30%	0%	0%
Forereef	686.95	30%	0%	12%
Pass	19.53	30%	0%	0%
Reef flat	740.84	30%	0%	9%
Diffuse fringing reef	114.37	30%	0%	54%
Channels	14.70	30%	0%	81%
Terrestrial	**10581.64**	**20%**	**8%**	29%
Freshwater Marsh	14.50	20%	0%	0%
Montane Cloud Forest	68.60	20%	1%	63%
Swamp Forest	542.41	20%	14%	20%
Upland Broadleaf Forest	5888.27	20%	8%	29%

Representation Gap Analysis Key Messages:

- If proposed PAs are formally designated, Kosrae will have made good progress towards achieving Micronesia Challenge targets for representation of marine and terrestrial areas within a state-wide protected area network.
- Where opportunities exist to review and potentially revise the boundaries of proposed MPAs prior to designation, consideration should be given to whether they could be moved or expanded to include areas of currently underrepresented habitat types: notably blue holes, passes and coral reef areas of the exposed reef system, and seagrass areas of the coastal barrier reef system. Attention should be given towards ensuring there is adequate protection for mangroves. This might be achieved by including protection for the mangroves adjacent to marine protected areas in Walung and Utwe, or those adjacent to the Yela Watershed conservation area. Alternatively other effective area-based management might be implemented to ensure sustainable use of the extensive mangrove areas in Utwe and Tafunsak.
- Existing and proposed terrestrial PAs do a good job at representing important upland forest types.

Ecological gaps

Ecological gaps assess the adequacy of protected areas to ensure the persistence of the features they are designed to protect; for example: do protected areas contain the habitat types that key species require, and are they large enough to encompass their daily movement patterns? This analysis focuses on the adequacy of Kosrae's marine protected areas in terms protecting locally important fish species.

To sustain target species within their boundaries, marine protected areas should be more than twice the size of the home range of focal species (in all directions), should include habitats that are critical to the life history of focal species (e.g. home ranges, nursery grounds, migration corridors and spawning aggregations), and be located to accommodate movement patterns among these. This will ensure that the protected area includes the entire home range of at least one individual, and will likely include many more where individuals have overlapping ranges.

Key fish species of interest for Kosrae are listed in Table 2, along with the recommended minimum MPA size to protect that species.

To calculate the effective size of existing MPAs in Kosrae, the ArcGIS Minimum Bounding Geometry tool was used to calculate the shortest distance between any two vertices of the convex hull of the MPA polygon. Comparison with the size of existing and proposed MPAs in Kosrae (Figure 6) highlights that many MPAs are too small to protect all species of interest.

Table 2. Key fisheries species of interest, and recommended minimum MPA sizes

English / Scientific name	*Kosraean name*	*Common Habitats*	*Minimum recommended MPA size*
Bumphead parrotfish / *Bolbometopon muricatum*	Komokut	Mangroves, seagrass, enclosed lagoons (blue holes), forereef, reef flat, pass, channels.	9.4 miles
Humphead wrasse / *Cheilinus undulatus*	Kuhsruhl	Mangroves, seagrass, enclosed lagoons (blue holes), forereef, reef flat, pass, channels.	12 miles
Bluefin trevally / *Caranx melampygus*	Lalot / srapsrap	Enclosed lagoons (blue holes), forereef, reef flat, pass.	6.6 miles [1]
Bigeye trevally / *Caranx sexfasciatus*	Lalot / srapsrap	Enclosed lagoons (blue holes), forereef, reef flat, pass.	1.2 miles [1]
Peacock hind / *Cephalopholis argus*	Kalsrik	Forereef, reef flat, pass, enclosed lagoons (blue holes).	0.12 miles
Highfin grouper / *Epinephelus maculatus*	Kalsrik	Forereef, reef flat, pass, enclosed lagoons (blue holes).	5 miles [1]
Steephead parrotfish / *Chlorurus microrhinos*	Mwesrik	Enclosed lagoons (blue holes), forereef, reef flat, pass.	2.6 miles [1]
Bullethead parrotfish / *Chlorurus sordidus*	Mesrik	Enclosed lagoons (blue holes), forereef, reef flat, pass.	1.5 miles
Long-nose parrotfish / *Hipposcarus longiceps*	Mwesrik	Enclosed lagoons (blue holes), forereef, reef flat, seagrass.	2.4 miles [1]
Banded goatfish / *Parupeneus multifasciatus*	Apihl / Sisiaf	Enclosed lagoons (blue holes), forereef, reef flat, seagrass.	1.4 miles
Humpback red snapper / *Lutjanus gibbus*	Srihnac / Niahluh	Mangroves, seagrass, enclosed lagoons (blue holes), forereef, reef flat,	3.7 miles
Striated surgeonfish / *Ctenochaetus striatus*	Kaput	Enclosed lagoons (blue holes), forereef, reef flat, seagrass.	0.4 miles
Lined surgeonfish / *Acanthurus lineatus*	Kaput	Enclosed lagoons (blue holes), forereef, reef flat.	0.6 miles
Orangespine unicornfish / *Naso lituratus*	Kaput	Enclosed lagoons (blue holes), forereef, reef flat.	2.6 miles
Bluespine unicornfish / *Naso unicornis*	Kaput	Enclosed lagoons (blue holes), forereef, reef flat, pass, channels.	0.6 miles
Mottled spinefoot / *Siganus fuscescens*	Mulap / Mweosra / Luhluhk	Seagrass, enclosed lagoons (blue holes), forereef, reef flat, mangroves.	2.6 miles
Golden-lined spinefoot / *Siganus lineatus*	Mulap / Mweosra / Luhluhk	Seagrass, enclosed lagoons (blue holes), forereef, reef flat, mangroves.	0.8 miles
Rudderfish / *Kyphosus* spp.	Won / Ikensahk / Eloh	Enclosed lagoons (blue holes), forereef, reef flat, pass.	1.6 miles
Emperors / *Lethrinus* spp.	Srinkap	Mangroves, seagrass, enclosed lagoons (blue holes), forereef, reef flat.	2.4 miles [1]

[1] NOTE - MPAs will need to be combined with other fisheries management measures to protect these species when they move outside MPAs

Ecological Gap Analysis Key Messages:

- Only species with very small home ranges, such as *Cephalopholis argus* and *Ctenochaetus striatus* are likely to be well protected within all existing MPAs.
- Improving protection for species with larger home ranges will require either making some MPAs larger, or alternative management measure for those species, such as catch, size, gear or effort restrictions, or seasonal catch and/or sale bans.
- Some species utilize different habitat types for foraging and resting, or at different stages throughout their life history, performing ontogenetic migrations between nursery, juvenile and adult habitats. For example, rabbitfish (*Siganidae*) have been found to be more abundant on reefs close to mangroves, and Bumphead parrotfish (*Bolbometopon muricatum*) requires shallow mangrove areas and seagrass meadows for nursery areas. MPAs with good habitat connectivity (i.e. they contain mangrove, and coral reef habitats within their boundaries, or are within close proximity to these) are likely to provide better protection for these species.
- Given the small marine habitat area for Kosrae, which imposes constraints on the size of MPAs, it is likely that complementary fisheries management strategies will be required to manage many species of local importance.

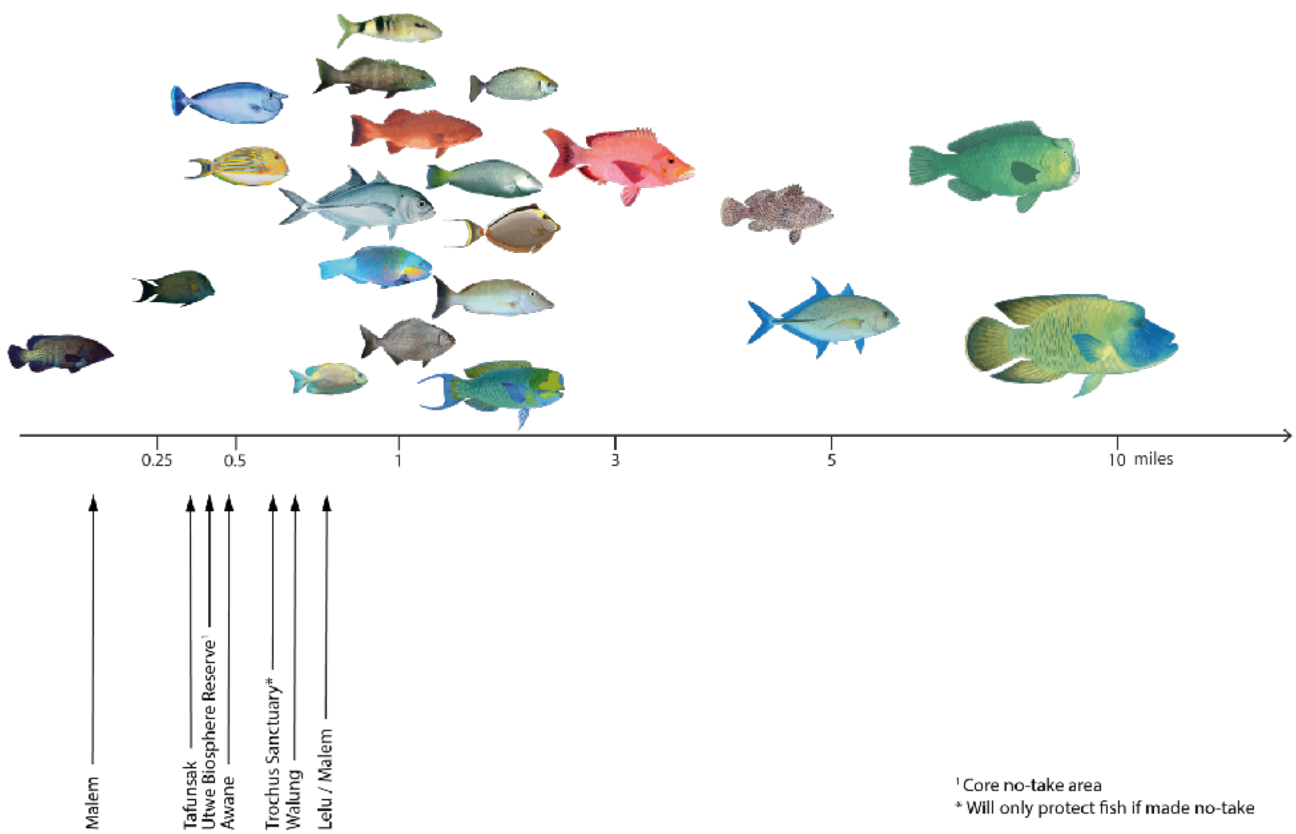


Figure 6. Home range movements of key fish species and effective sizes of existing and proposed marine protected areas in Kosrae

Management Gaps

An MPA effectiveness assessment tool has been developed for Micronesia, modelled after the Indonesian MPA Management Effectiveness (MPAME) tool. This allows for enhanced understanding of management effectiveness of existing MPAs to be taken into consideration in the PAN design.

During assessment, evaluators answer a series of questions to score the management effectiveness of the MPA in 11 different categories: biophysical, conservation effect, enforcement, finance, infrastructure & equipment, legal, planning, socioeconomic, staffing, stakeholder engagement, and traditional knowledge. Each of the categories are attributed a management effectiveness level which represent a chronological management continuum from initiation of a new MPA (Level 1) to a fully institutionalized MPA (Level 5).

MPAME assessments have been performed for Utwe Biosphere Reserve (July 2018), Tafunsak MPA (January 2019) and Malem MPA (January 2019). Critical challenges to achieving management effectiveness (i.e. barriers at Level 1 or Level 2) were identified as follows:

Utwe Biosphere Reserve

- [Finance] The management plan describes a budget, but it is not adequate or detailed enough to support operations.
- [Infrastructure & equipment] There are no facilities to support the protected area staff and operations; There is no equipment to support the protected area staff and operations.
- [Staff Capacity and Development] Staffs are untrained, or the protected area is not fully staffed; Training or capacity building opportunities are not available, or staffing levels are not adequate to warrant training opportunities.

Tafunsak

- [Staff Capacity & Development] The management plan identifies required staff position, but the positions are not well defined or realistic.
- [Biophysical] There have been limited biophysical baseline assessments completed for the site; the information on the biophysical conditions is not sufficient to support planning and/or decision.

Malem

- [Infrastructure & equipment] There are no facilities to support the protected area staff and operations; There is no equipment to support the protected area staff and operations.

A low overall score is not surprising or cause for alarm for MPAs that are still in the early stages of establishment. However, efforts to expand or establish new PAs should be balanced with the need to continue to improve the management effectiveness of existing MPAs.

Spatial conservation prioritization

Spatial conservation prioritization aims to identify priority areas where new conservation areas might be established to fill gaps in an existing PAN.

Methods

Marxan

Marxan (http://www.uq.edu.au/marxan/) is a decision-support tool that assists users to design protected area networks that achieve specified conservation objectives, while minimizing negative social and economic impacts. When provided with information on the amount of each biodiversity feature (e.g. habitat types) in each planning unit, Marxan identifies sets of planning units that achieve biodiversity representation targets in an efficient manner. Each Marxan "solution" comprises a set of planning units that achieves specified representation targets. When run multiple times, Marxan also produces a "selection frequency" output which indicates the number of times that each planning unit was selected for inclusion in a protected area network that achieved the representation targets. Sites that have a high selection frequency are more likely to be important to achieve the conservation objective.

Marxan's cost minimisation function allows users to express a preference for including or avoiding particular sites that are assigned a lower or higher "cost", respectively. Marxan will still select planning units to achieve the representation objectives above, but when deciding which planning units to select, it will choose those that have a lower "cost". Cost layers can include an economic cost estimate (i.e. $ value) associated with protecting different sites, but more commonly incorporate estimates of opportunity costs (e.g. negative impact on resource users), local preferences, or habitat quality information.

Because Marxan finds efficient solutions (i.e. seeking to minimize cost), it is common for solutions to propose lots of small, scattered, protected areas. Unless planning units are very large (which creates other problems), such solutions are unlikely to be feasible to implement, or effective for conserving biodiversity (due to small size and edge effects). For this reason, Marxan allows users to adjust a boundary length modifier (BLM) parameter, which places increased importance on minimizing the total boundary length of protected areas, in addition to minimizing cost. Using the BLM has the effect of creating fewer, larger protected areas.

Spatial prioritization scenarios

To facilitate the prioritization analysis, the planning regions were first divided into "planning units" which form the building blocks of protected area network designs. Each planning unit can be selected for inclusion in a network, or left open to alternative uses; different management zones were not considered. The planning units used for analysis were 25 ha, for consistency with recent conservation prioritizations conducted for other FSM states.

Feature Representation Objectives

Habitat representation targets were set following the Micronesia Challenge: 20% for all terrestrial habitats and 30% for all marine habitats (mangroves were considered as a marine habitat). Representation targets were not set for secondary vegetation and built up areas, or for agroforestry areas, since these are required for local use.

Table 3. Locally important habitats, species, special and unique features identified by participants at the February 2019 PAN workshop

Features	*Key Threats*	*Recommendation*	*Include in spatial prioritization?*
Habitats			
Coral reefs	Sedimentation, pollution, COTS, bleaching	Ensure representation in PAN	Yes, Adopt Micronesia Challenge representation target of 30%
Seagrass	Sedimentation, pollution	Ensure representation in PAN	Yes, Adopt Micronesia Challenge representation target of 30%
Lagoon	Sedimentation, pollution	Ensure representation in PAN	Yes, Adopt Micronesia Challenge representation target of 30%
Blue hole	Sedimentation, pollution	Ensure representation in PAN	Yes, Adopt Micronesia Challenge representation target of 30%
Channels	Sedimentation, pollution	Ensure representation in PAN	Yes, Adopt Micronesia Challenge representation target of 30%
Mangrove forest	Overharvesting, pollution	Ensure representation in PAN	Yes, Adopt Micronesia Challenge representation target of 30%
Swamp	Development projects	Ensure representation in PAN	Adopt Micronesia Challenge representation target of 20%
Terminalia / ka forest	Development projects	Ensure representation in PAN	Yes, Adopt Micronesia Challenge representation target of 20%
Watershed areas	Development projects, erosion	Employ sustainable land use practices within priority watersheds	No
Rivers & streams	Development projects, pollution, sedimentation	Prioritise riparian buffers for forest conservation or management rules	Yes, riparian buffers of rivers reduce cost of protecting forest habitat
Upland forest	Development projects	Ensure representation in PAN	Yes, Adopt Micronesia Challenge representation target of 20%
Agroforestry areas	Development projects		No
Species			
Food fish species	Overharvesting	Ensure representation of habitat in PAN, ensure MPAs are adequate for key species	Yes, Representation targets for coral reefs, seagrass, lagoons; adequate MPA design
Sea turtle		Ensure representation of critical habitat in PAN	Yes, reduce cost of nesting beaches

Sea cucumber	Overharvesting	Ensure representation of habitat in PAN	Yes, Representation targets for coral reefs, seagrass, lagoons
Clams	Overharvesting	Ensure representation of habitat in PAN	Yes, Representation targets for coral reefs
Mangrove crabs	Overharvesting	Ensure representation of habitat in PAN	Yes, Representation targets for mangroves
Micronesian pigeon	Habitat loss, hunting	Ensure representation of habitat in PAN	Yes, Representation targets for upland forest
Noni trees		Ensure representation in PAN	Yes, Representation targets for coastal forest
Special & Unique features			
Fish spawning aggregation sites		Include in no-take MPAs where possible	Yes
Lelu ruins		Manage access to historical and cultural sites	No
Mosral reef		Prioritize for inclusion in PAN	Yes, reduce cost
Fruit bats roosting area		Prioritize for inclusion in PAN	Yes
Swiftlet / kalkuef nesting cave		Prioritize for inclusion in PAN	Yes

Ensuring representation of critical habitat types within the PAN will also afford protection to locally important species, including food fish species, sea cucumbers, clams, mangrove crabs, *ka* trees (*Terminalia carolinensis*), and the Micronesian pigeon (Table 3).

To ensure the equitable distribution of protected areas across Municipalities and around the island, all habitat types were stratified by Municipality.

For all prioritization scenarios, the feature spf values were parameterized so that all Marxan solutions would achieve all representation objectives to within 1% (i.e. if 99% of the required area was included, the solution was considered acceptable).

Cost Layers

- Increased costs for including sites with degraded habitat quality in the PAN

Information provided by participants at the February 2019 PAN workshop identified some areas which were considered less suitable for protected area designation, either because they had degraded habitat quality (e.g. due to erosion, sedimentation, pollution, or landfill), or because they were sites upon which local resources were heavily dependent. The “cost” of protecting these areas was increased, to reduce the likelihood that they would be selected by Marxan for inclusion in protected area network designs (Figure 7).

- Decreased costs for including special and unique features and riparian forest buffers in the PAN

The “cost” of including planning units containing special and unique features, including sea turtle nesting beaches, fish spawning aggregation sites, fruit bat roosting areas, a swiftlet (*kalkuef*) nesting cave and

Mosral reef (identified as unique / biodiverse) were reduced to favour their inclusion in protected area network designs (Figure 8).

Workshop participants identified rivers, streams and riparian buffers (the strip of vegetation alongside a waterway) as a conservation priority, due to the negative impact of pollution and sedimentation on downstream habitats. Riparian buffers can increase freshwater biodiversity, reduce erosion and downstream sedimentation. To account for this in spatial prioritization, 100 m riparian buffers were identified using GIS, and the "cost" of protecting forest habitats within these buffers was reduced, increasing the likelihood that they would be selected by Marxan for inclusion in protected area network designs (Figure 9).

- Increased costs for sites with good fishing access

Under the assumption that marine areas that are easily accessible to fishers would be preferred fishing grounds and therefore less feasible for protected area implementation, the "cost" of protecting these areas was increased. Fishing accessibility was modelled as a function of proximity to populated places and marinas (for boat-based fishing), and the number of fishers (from household census data) and boats; i.e. areas closest to populated places with a larger number of fishers were assigned a higher cost than those further away, or close to a populated place with fewer fishers (Figure 10).

The overall "cost" of each planning unit (Figure 11) was calculated as:
Cost = (PU Area in ha) - (riparian buffer area + special & unique feature area) + (threat area + fishing cost)

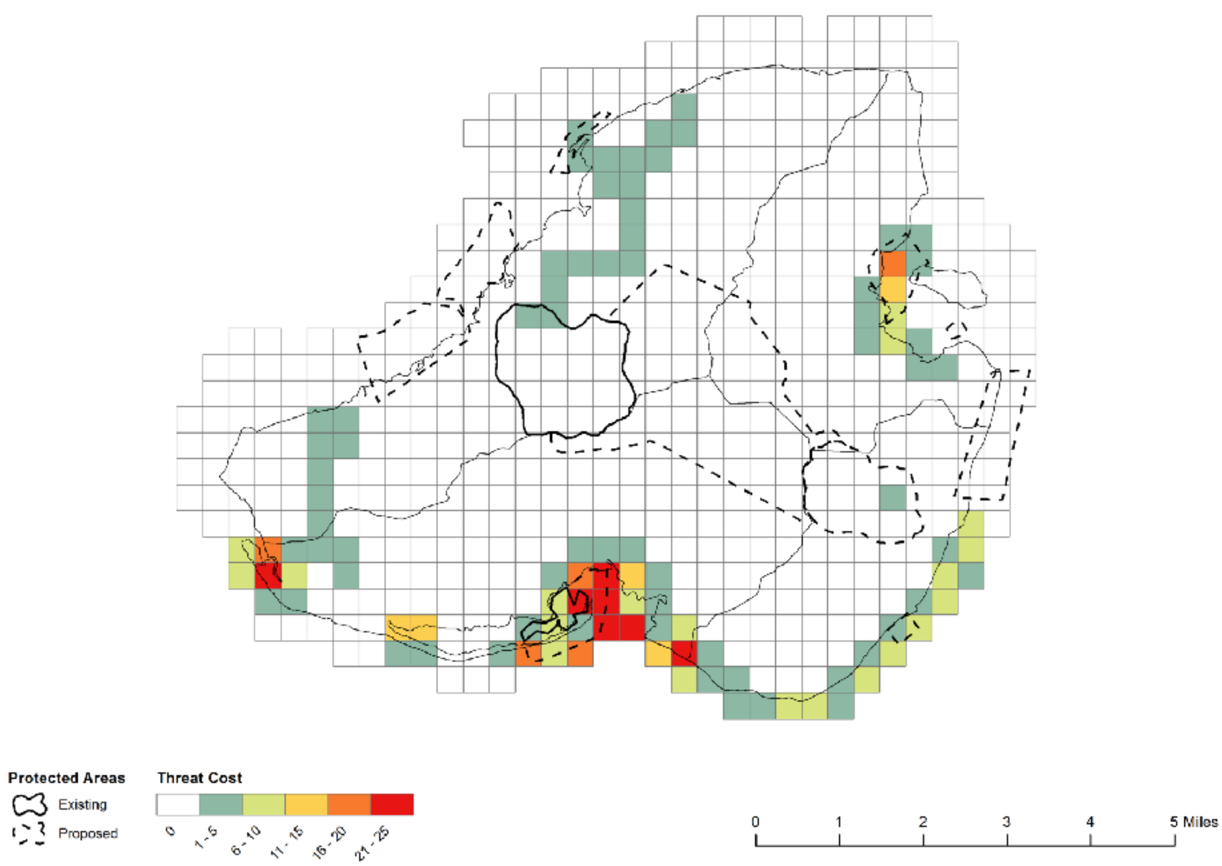


Figure 7. Increased costs for planning with degraded habitat quality

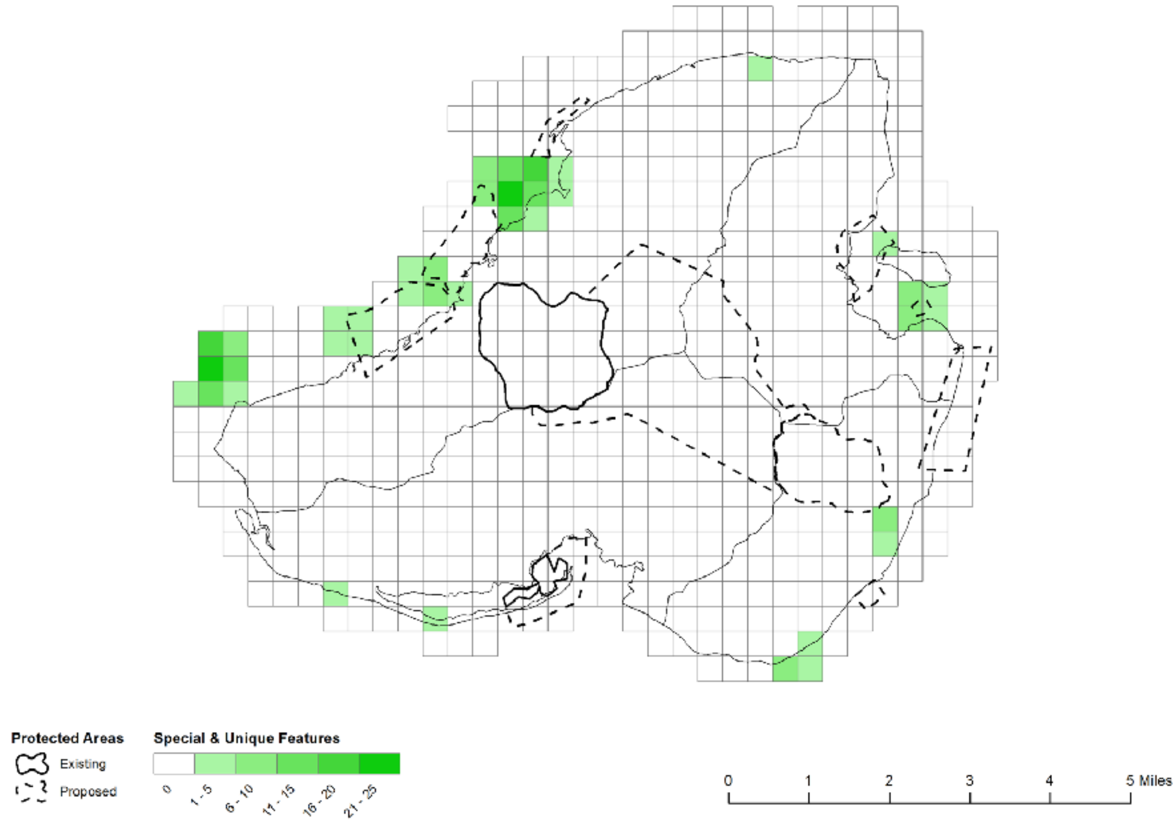


Figure 8. Decreased costs for planning units containing special and unique features

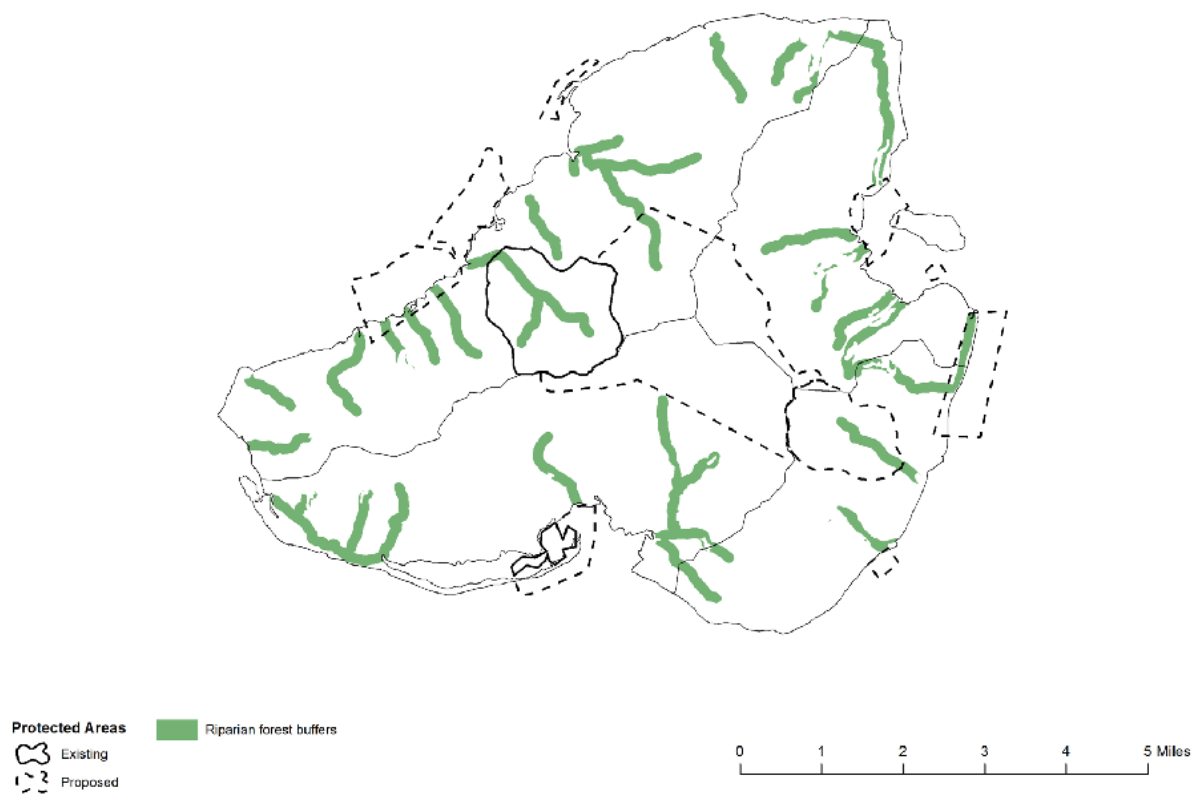


Figure 9. 100m riparian buffers

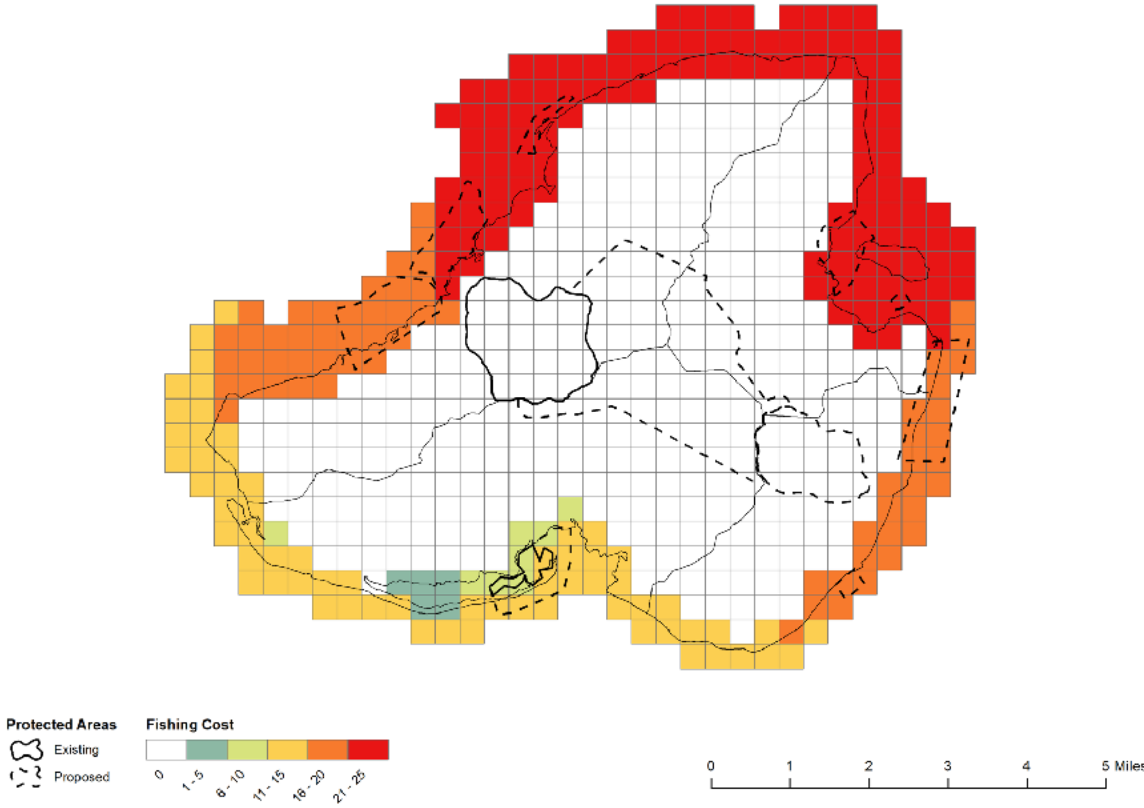


Figure 10. Increased costs for planning units accessible to fishers

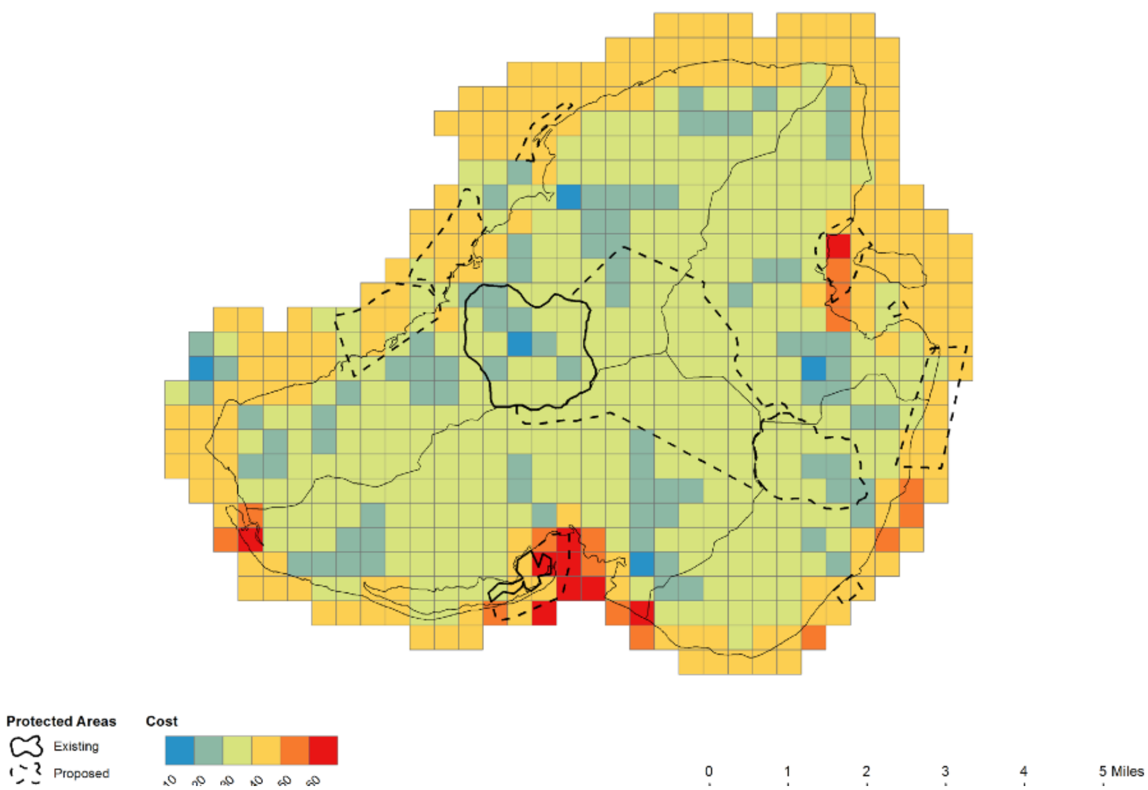


Figure 11. Total planning unit cost for Marxan spatial prioritization scenarios

Existing and Proposed Protected Areas

- Planning units central to existing & proposed protected areas locked into solutions

Given that Kosrae has few existing protected areas but several that have been proposed (Figure 1), it was not considered appropriate to lock the boundaries of these areas into Marxan solutions. Instead, only planning units that are completely within the boundaries of existing or proposed PAs were required to be included in Marxan solutions; this has the effect of requiring that PAN solutions include protected areas within the areas that have been proposed by communities, but allows flexibility in how the boundaries of those areas are configured.

Results

The spatial prioritization results presented below are all with respect to achieving Micronesia Challenge representation targets for 30% of marine (including mangrove) habitats and 20% of terrestrial habitats. Increasing or reducing these targets would result in more or less area being required, however it is unlikely that different areas would be prioritized.

Figure 12 indicates conservation priority areas for developing Kosrae's PAN. Planning units with a higher selection frequency are more important for achieving the specified conservation objectives. This scenario accounts for variable planning unit costs (see Figure 11) to avoid selecting areas noted as having degraded habitat quality or that are important fishing grounds, and to preferentially include areas that contain special and unique conservation features.

Figure 13 shows two example protected area network designs. Note that planning units with high selection frequency in Figure 12 are included in both solutions; differences between the two outputs indicate flexibility in how representation targets might be achieved.

Figure 14 shows the impact of requiring that existing and proposed protected areas are included in PAN designs: planning units in red are selected more frequently when these areas *are* required to be included in Marxan solutions; those in blue are selected more frequently when existing and proposed protected areas are disregarded. Areas more important when existing and proposed protected areas are not included might occur because proposed protected areas coincide with areas of high threat or cost, for example in the Utwe Biosphere Reserve and proposed PA in Lelu (see Figure 11). When not required to be included, the proposed Mahkontowe Conservation Area is selected less frequently than forested areas in Utwe, likely because these include riparian buffers (Figure 9), which were prioritised for inclusion (through a lower cost value, Figure 11).

It is important to note however that proposed protected areas indicate some level of existing community willingness to undertake conservation or management actions; this is often more important than meeting representation targets or finding a protected area network with the lowest possible "cost".

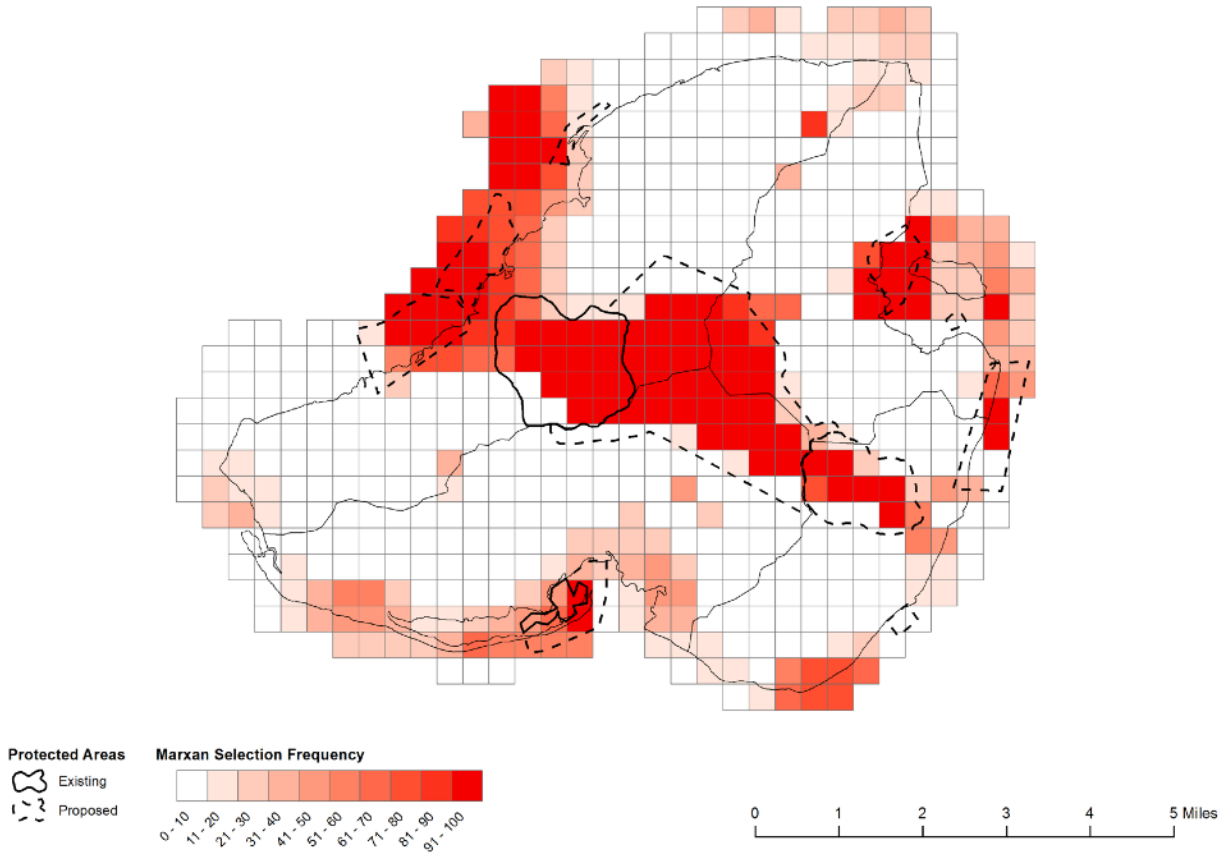


Figure 12. Marxan selection frequency output, indicating conservation priorities for Kosrae. Existing and proposed protected areas are prioritised for inclusion in PAN designs.

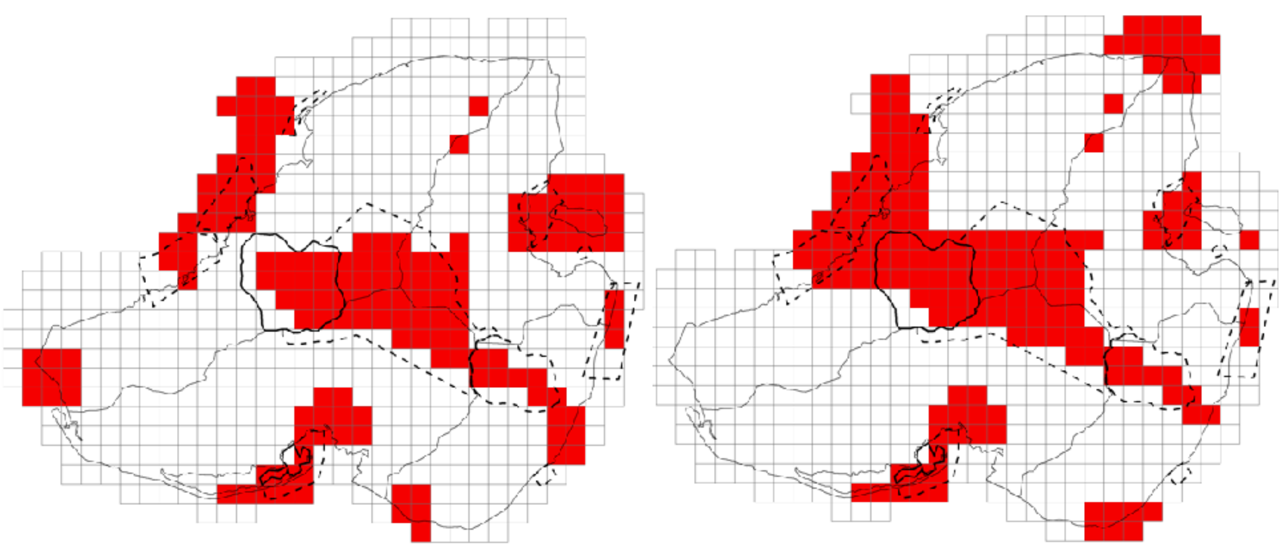


Figure 13. Two alternative protected area network designs that achieve representation targets whilst minimising planning unit cost.
Existing and proposed protected areas are prioritised for inclusion in PAN designs.

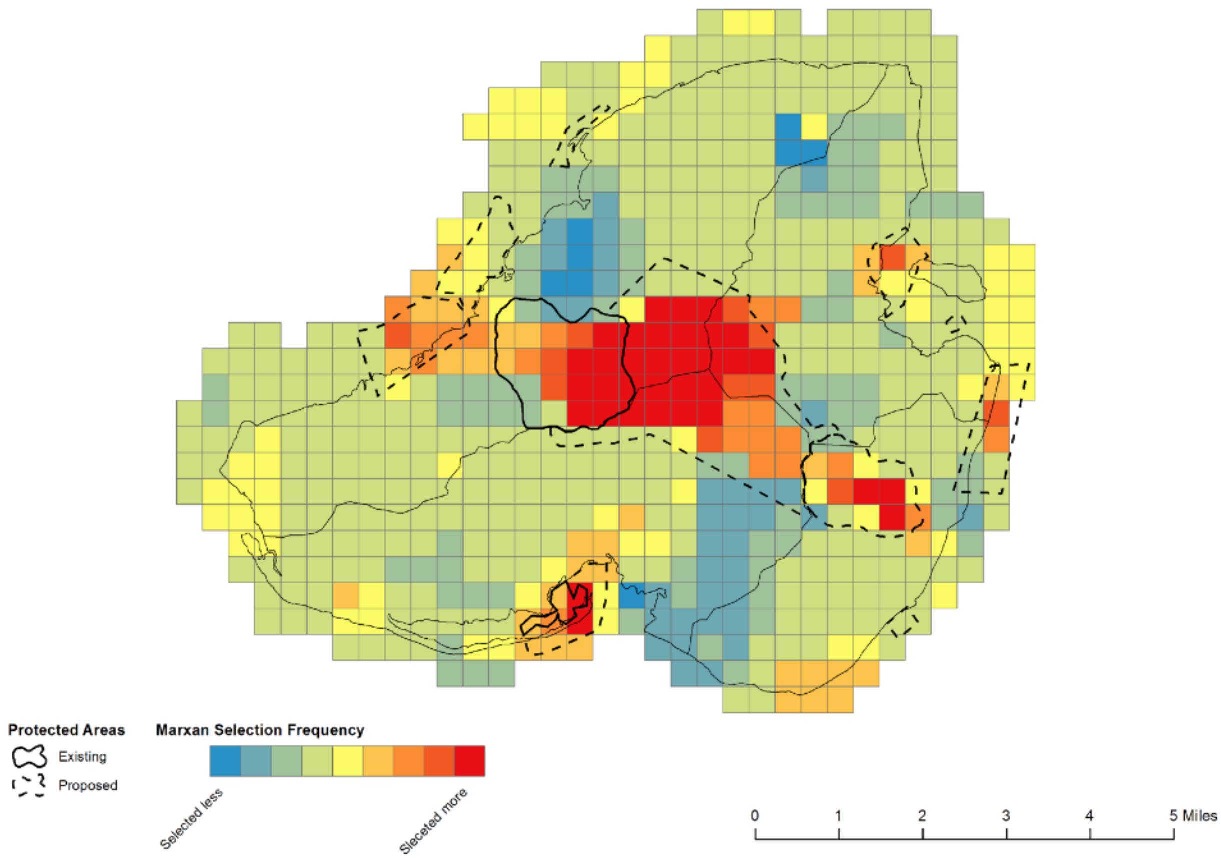


Figure 14. Difference map showing how including existing and proposed protected areas changes PAN network designs.
Planning units in red are selected more frequently when existing and proposed protected areas are required to be included in Marxan solutions; those in blue are selected more frequently when existing and proposed protected areas are disregarded.

Recommendations for improving the design of Kosrae's PAN

Marine protected area design

For existing and proposed marine protected areas, communities should consider whether their current design is likely to benefit the species that they care about most, using the information provided in Table 2 and Figure 6, and the MPA Scorecards below. This information can also be used to interpret and refine ecological monitoring efforts: for example, species with home range sizes much greater than an MPA's effective size should not be expected to increase in abundance. However, if monitoring indicates that the MPA is not working to increase the abundance of species that should be protected within its boundaries, there might be problems with compliance or management effectiveness that need to be addressed.

Terrestrial protected area design

Additional protected areas proposed for the Mahkontowe and Olum Watersheds would create a large contiguous protected area in the centre of Kosrae island, which would afford a good level of protection for most terrestrial habitat types, and the species which inhabit them. At present, riparian forest buffers within several watersheds are not protected; these features might be protected through targeted management rules (e.g. no cutting or logging within 100m of rivers and streams) rather than the designation of more extensive protected areas.

Threats within proposed protected areas

Figure 11 indicates several areas where threats to habitat quality have been identified within proposed protected areas, for example: sedimentation and erosion in the Utwe Biosphere Reserve, and poor water circulation in the proposed MPA in Lelu. Consideration should be given to whether protected area designation will help to overcome these threats, or, if not, whether more suitable (i.e. better quality) areas might be protected instead.

Missed opportunities

Figure 8 shows that the locations of many special and unique features identified by participants at the PAN design workshop do not coincide with proposed protected areas. This is notably the case for reef fish spawning aggregations in Tanfunsak, and the Mosral Reef in Malem.

Reef fish spawning aggregations are especially vulnerable to overfishing, and for this reason are typically prioritized for inclusion in marine protected area networks. If it is not feasible to protect these locations with no-take areas, alternative management strategies might be implemented. These could include a ban on fishing during the peak spawning season for key species (this may require several short closures at monthly intervals, as some species appear to aggregate around the period of the new moon).

Communities in Malem should consider whether the unique values they attributed to the Mosral Reef might be threatened by continued resource extraction, or, conversely, conserved through its designation as a protected area.

Complementary management strategies

Given Kosrae's small area, it is unlikely to be feasible to add further protected areas to Kosrae's PAN, beyond those that have already been proposed. Thus, there is clearly a role for alternative and complementary management strategies to help achieve local conservation objectives.

Complementary management strategies for coral reef associated fisheries could include size limits, seasonal closures (e.g. during spawning months), gear limits (e.g. night spearfishing ban in Pohnpei), exports bans or limits (eg. Palau reef fish export ban), catch quotas (e.g. Guam total allowable catches), or bans on commercial harvesting (e.g. subsistence fishing areas in Palau). Some such regulations already exist in Kosrae.

In terrestrial habitats, land use rules might help to overcome many threats to biodiversity and ecosystem health associated with watershed pollution, erosion and downstream sedimentation. These might include bans on logging or cutting vegetation within riparian buffers, restricting mangrove cutting to more sustainable species, and restricting the location of dump sites and pig pens near freshwater sources.

Marine Protected Area Scorecards

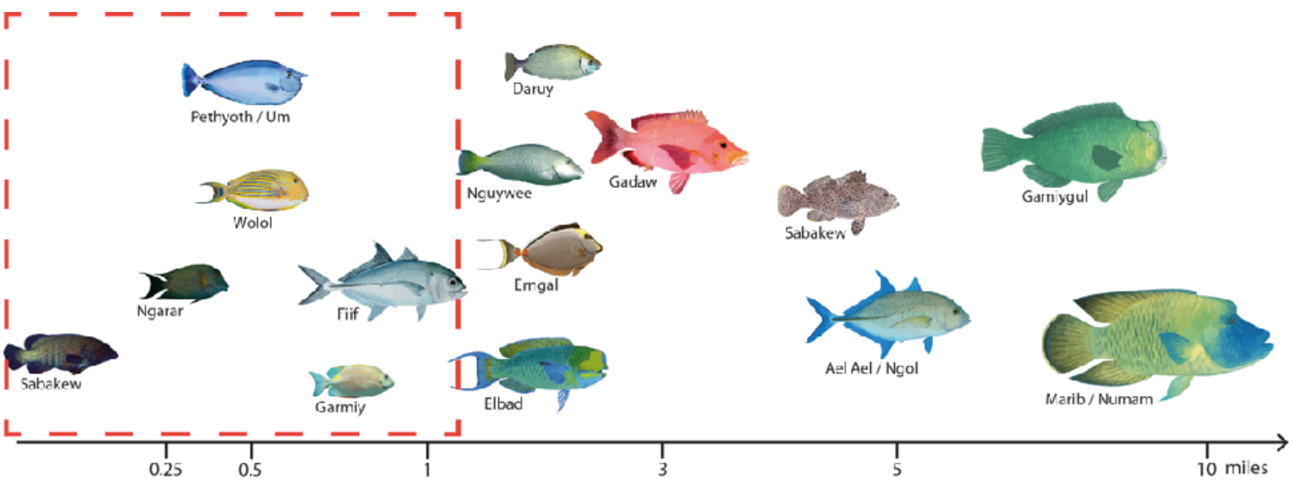
How to use the MPA scorecards

Habitat types

The first piece of information contained on the scorecard is the legend of habitat types which might be included within the MPA boundary. (left). It is important that the MPA contains the primary habitat types utilized by key fish species. For example, rabbitfish typically inhabit shallow seagrass beds, lagoons and the reef flat. If protecting these species is an objective for the MPA, it should contain those habitat types. Other species, such as groupers and unicornfish prefer the forereef habitat.

Adequacy for key fish species

The schematic below uses information on reef fish home range size and the effective size of the MPA to indicate which species will be adequately protected within the MPA. The red dashed box indicates the effective size of the MPA. Species within the box are adequately protected. Species that are not within the box are not adequately protected - if the boundaries of the MPA cannot be extended, alternative fisheries management will be required to protect these species.



Seascape connectivity

Finally, the distance from the MPA boundary to the nearest patch of seagrass and mangrove habitat is indicated (right). This is a proxy for how well connected MPAs on reef habitats are to potential nursery habitats for many reef fish species. Ideally, seagrass, mangrove and reef habitats will be within the MPA boundary. Where this isn't possible, placing MPAs close to those habitat types (and lagoon reefs) is a good idea.

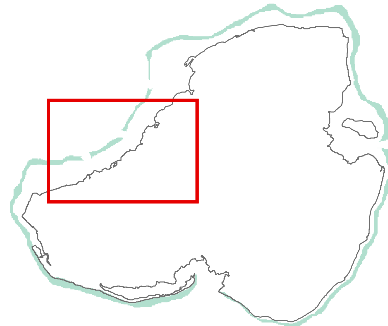
distance to seagrass = 0 miles

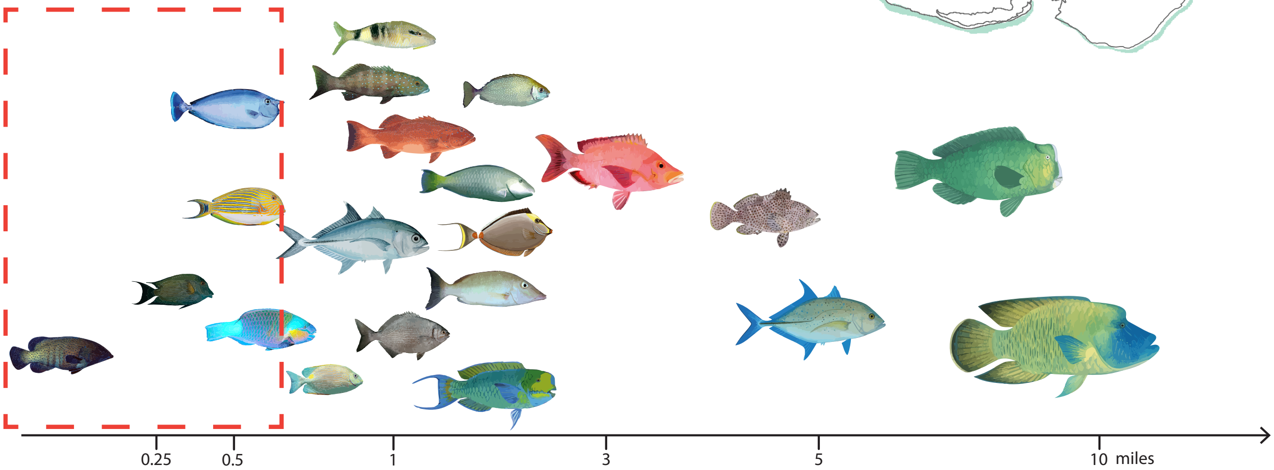
distance to mangroves = 0.3 miles

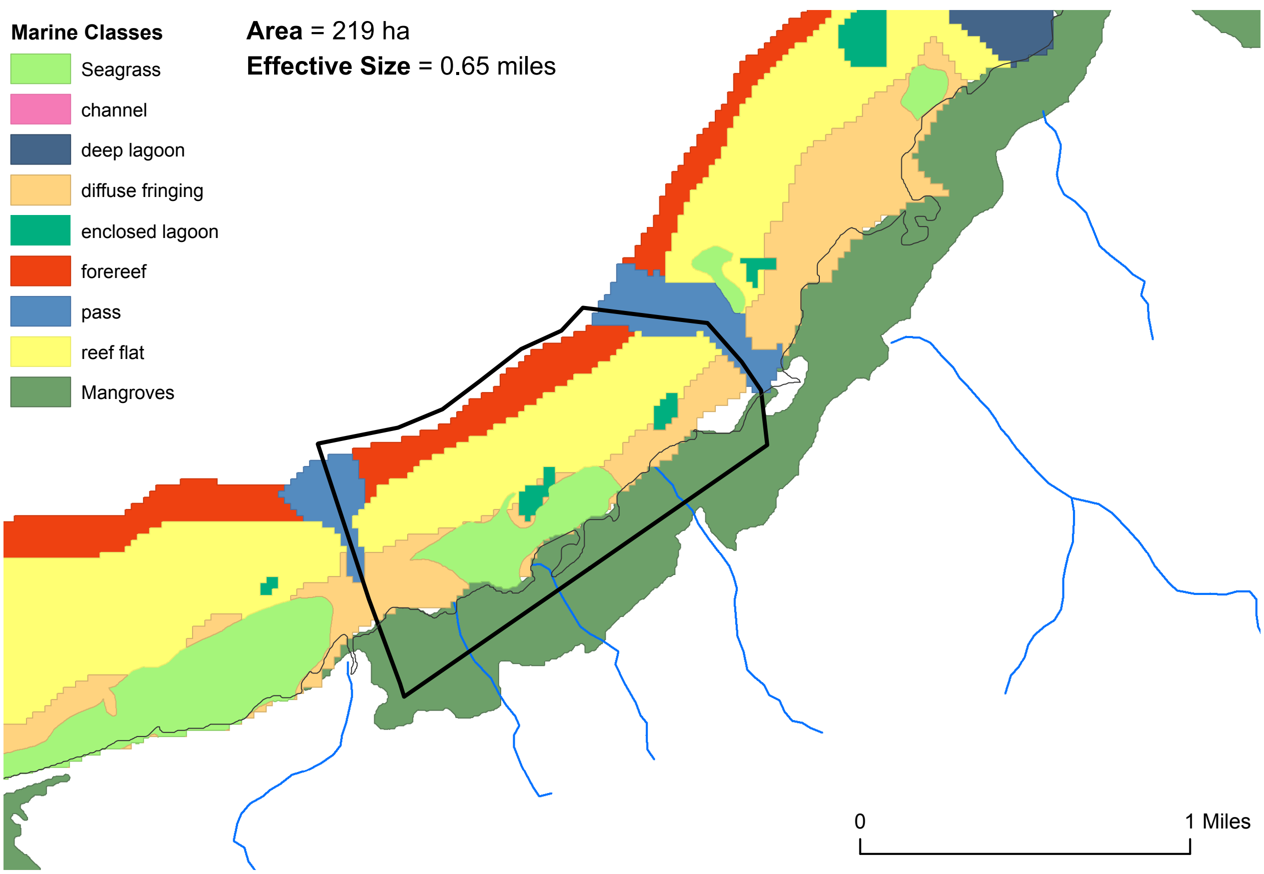
Walung Proposed Marine Conservation Area

Distance to mangroves = 0 miles

Distance to seagrass = 0 miles





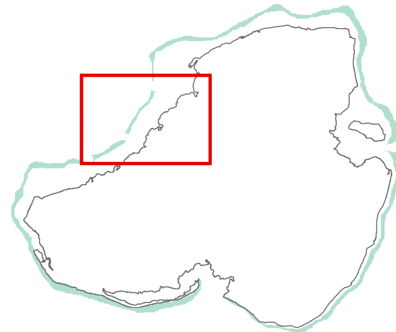


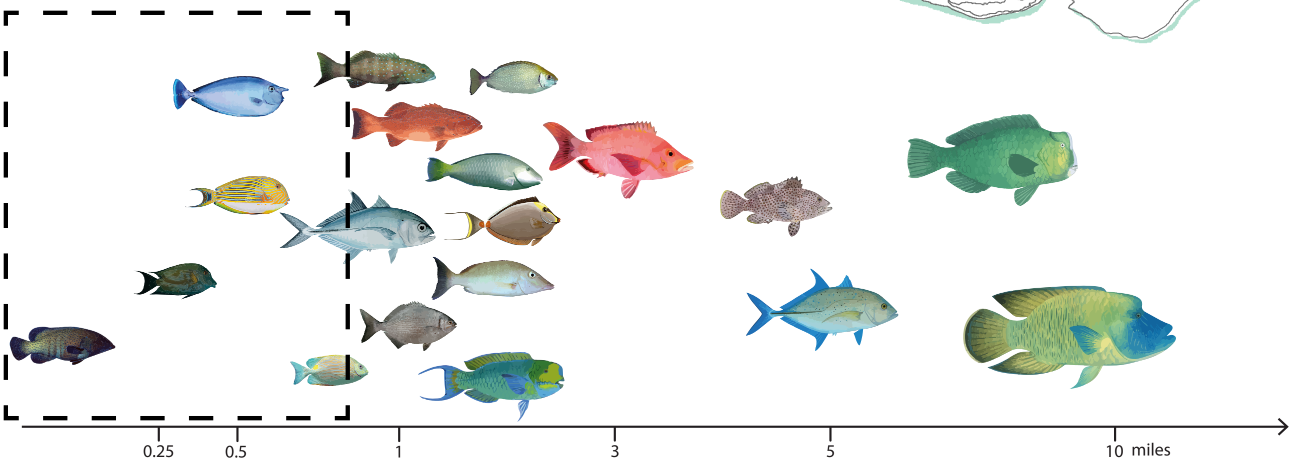
Trochus Sanctuary

*NOTE will only protect fish if made no-take

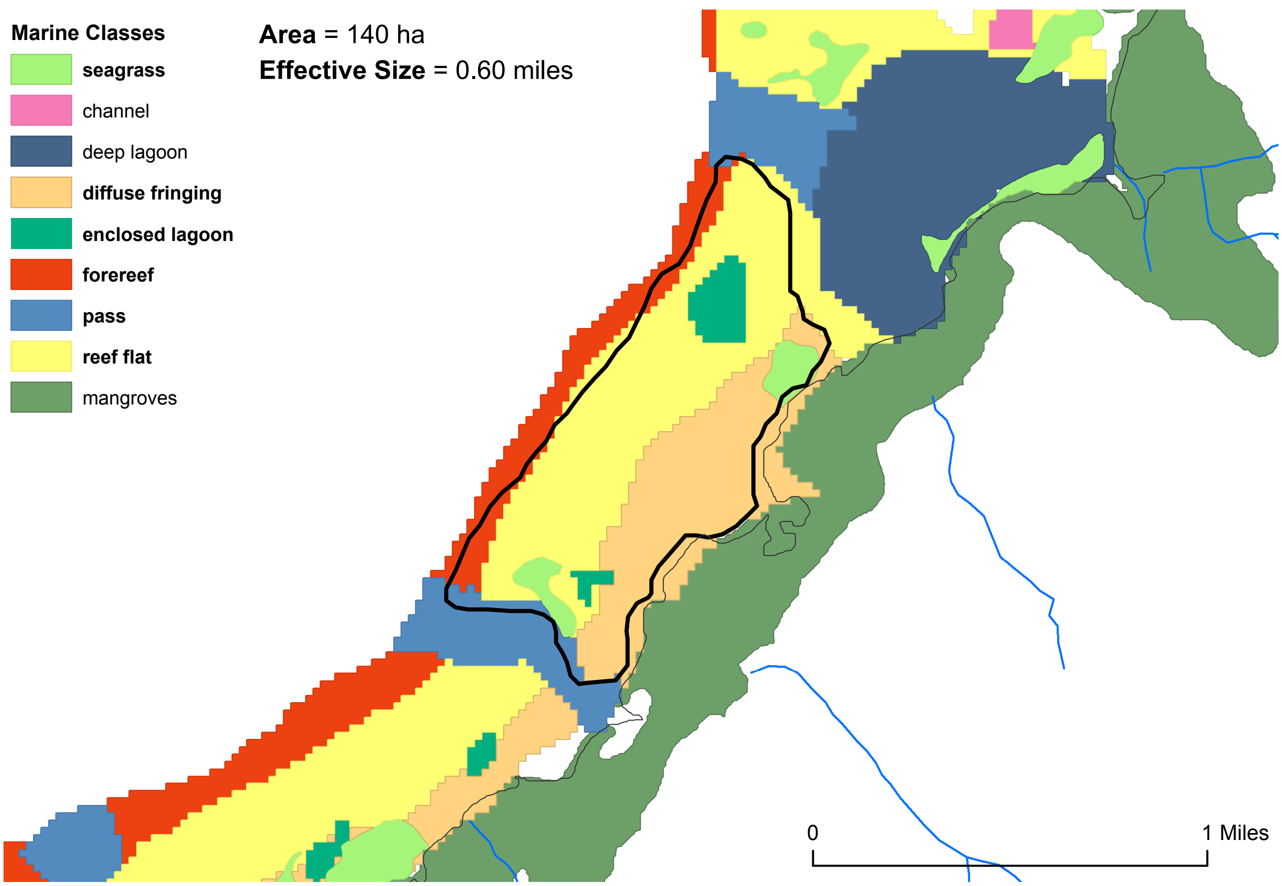
Distance to mangroves = 0.1 miles

Distance to seagrass = 0 miles

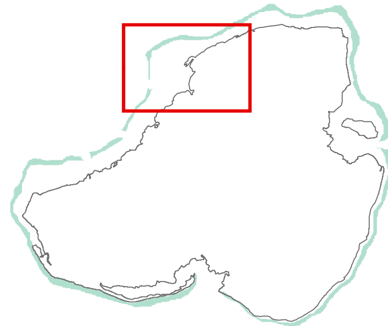




Area = 140 ha
Effective Size = 0.60 miles

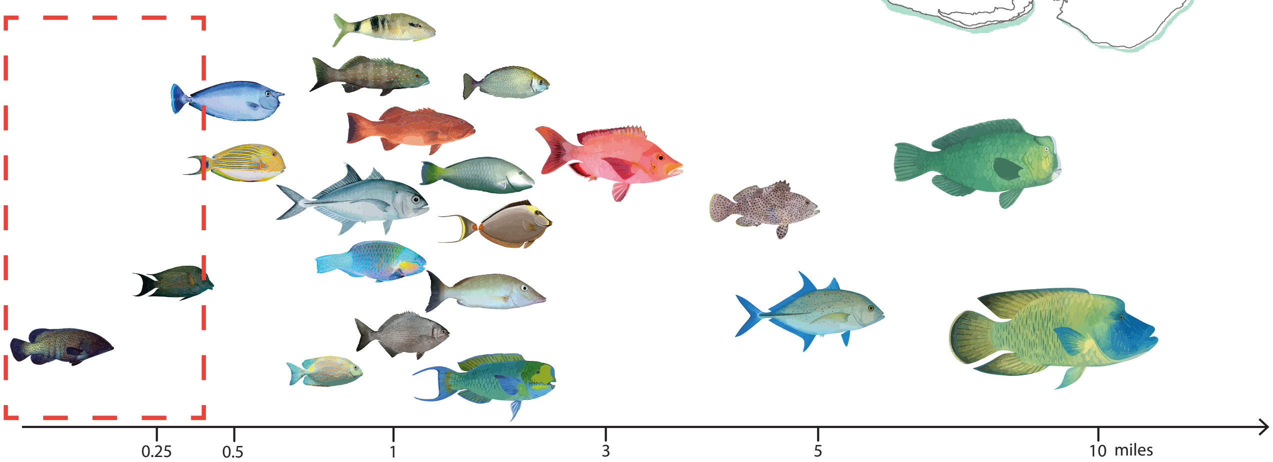


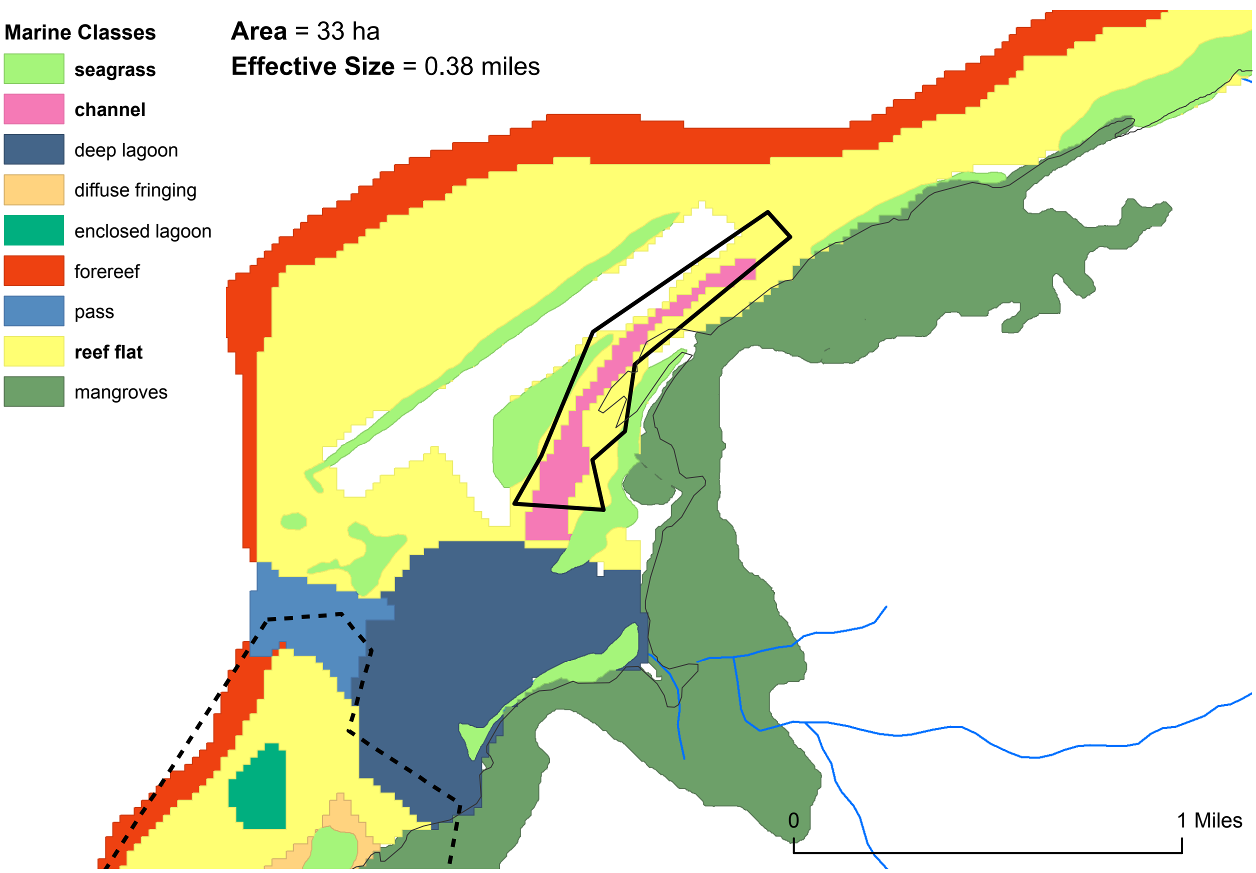
Tafunsak Proposed Marine Conservation Area



Distance to mangroves = 0.1 miles

Distance to seagrass = 0 miles

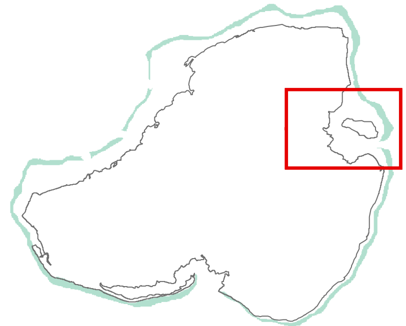


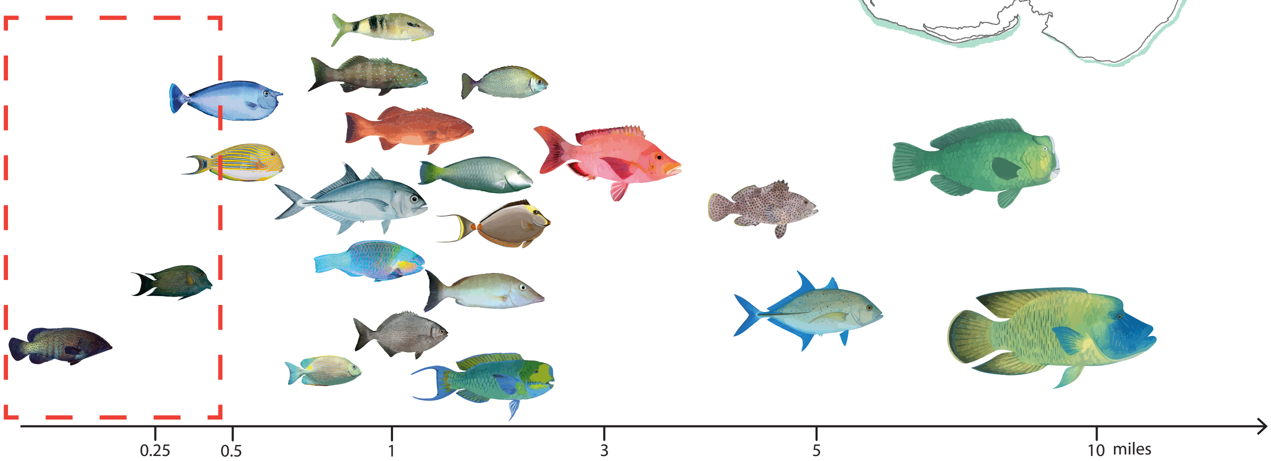


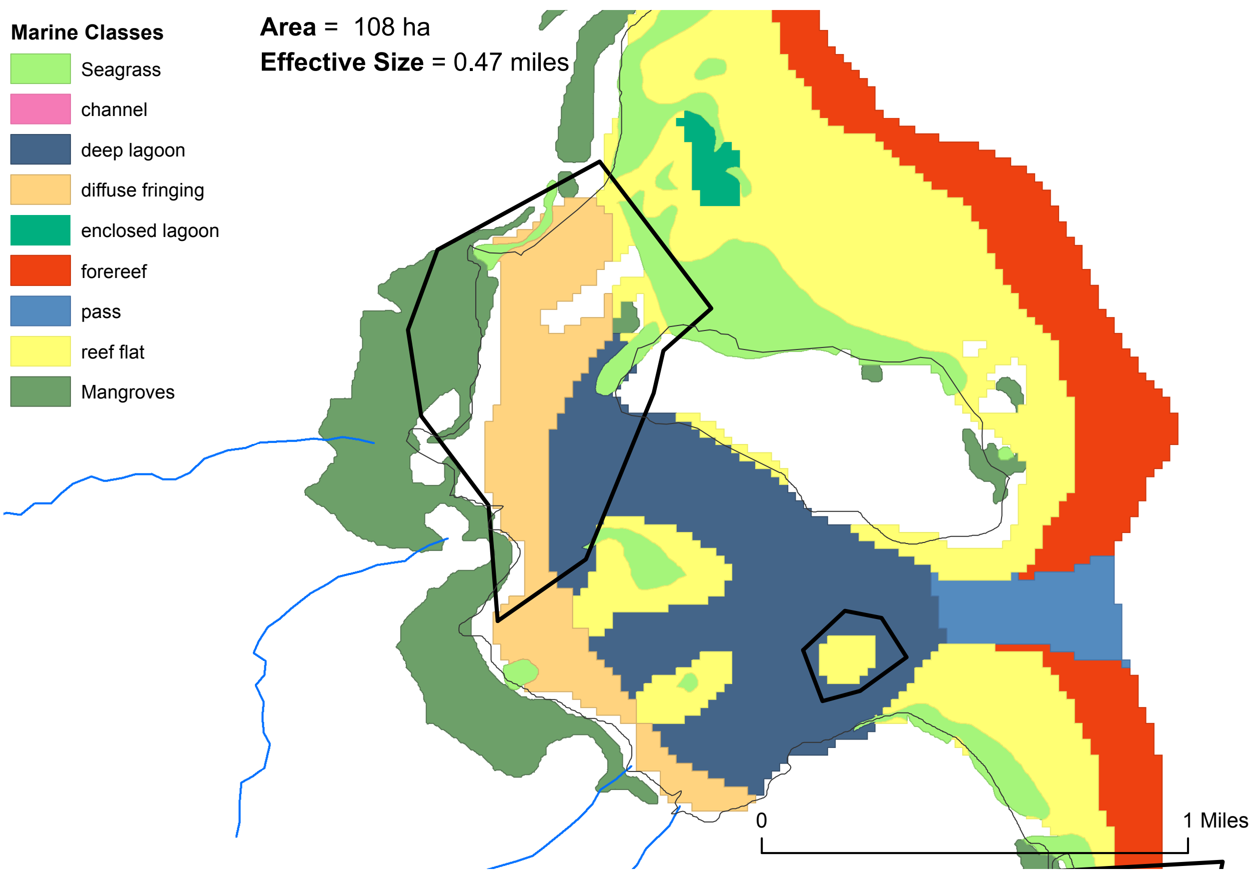
Awane Proposed Marine Conservation Area

Distance to mangroves = 0 miles

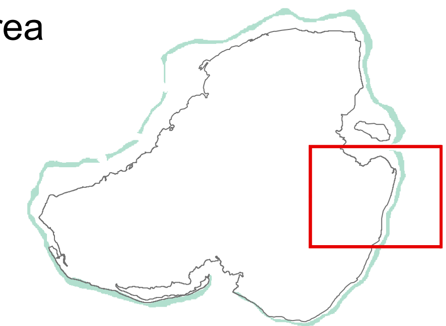
Distance to seagrass = 0.1 miles





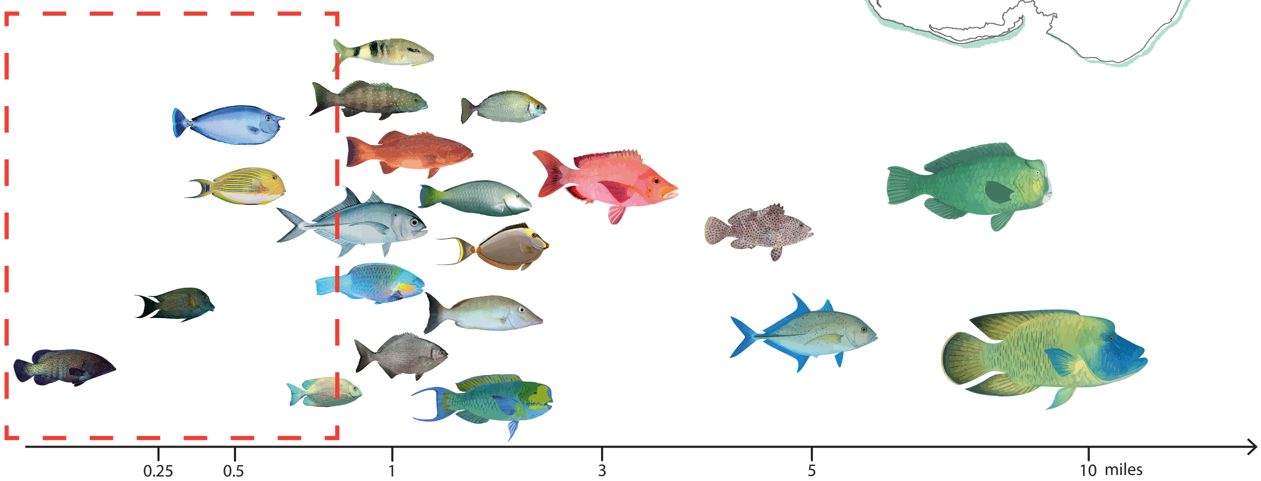


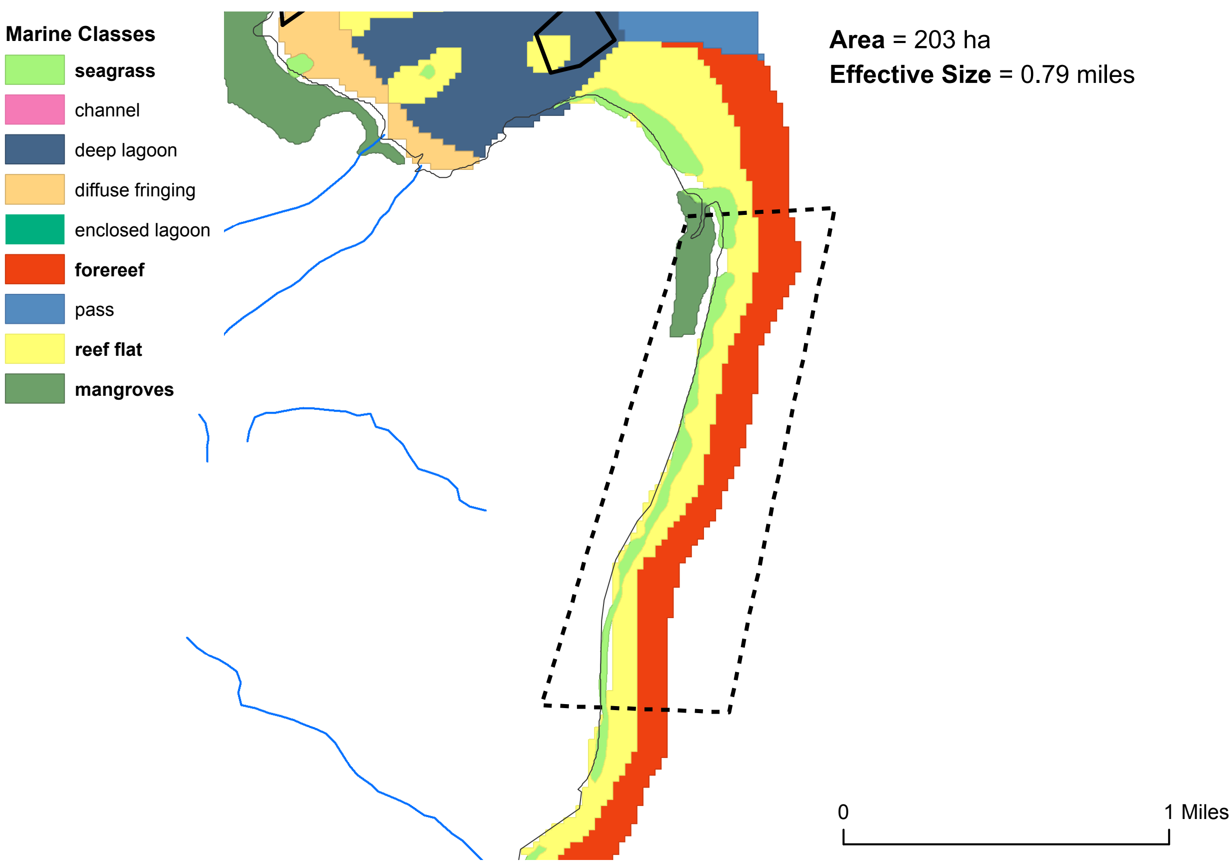
Lelu / Malem Proposed Marine Conservation Area



Distance to mangroves = 0 miles

Distance to seagrass = 0 miles





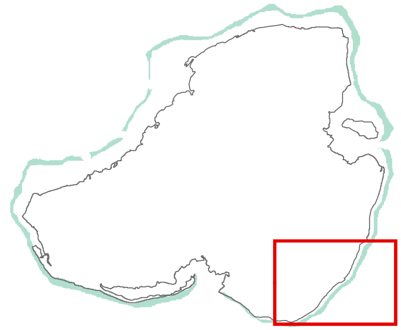
Area = 203 ha

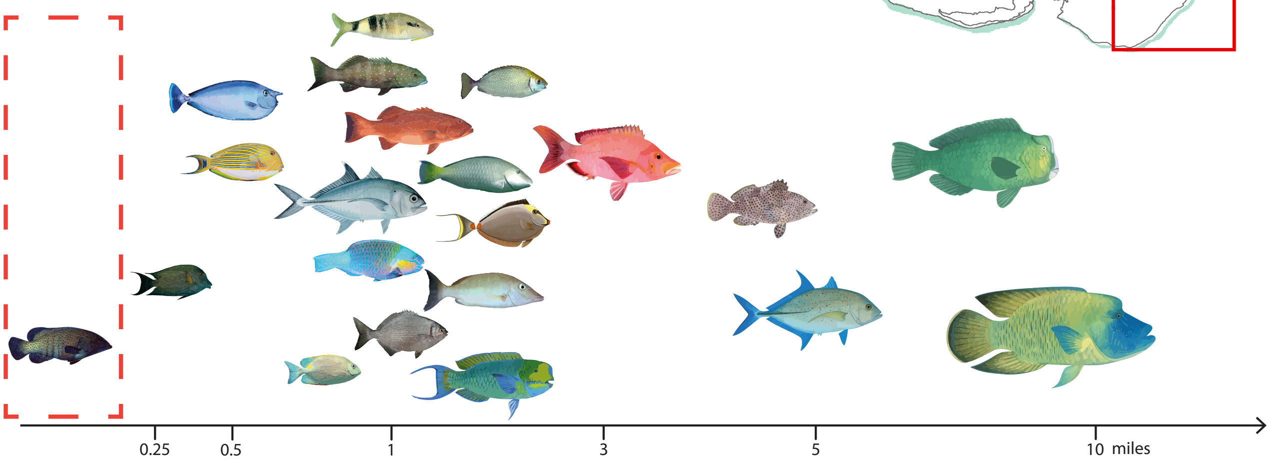
Effective Size = 0.79 miles

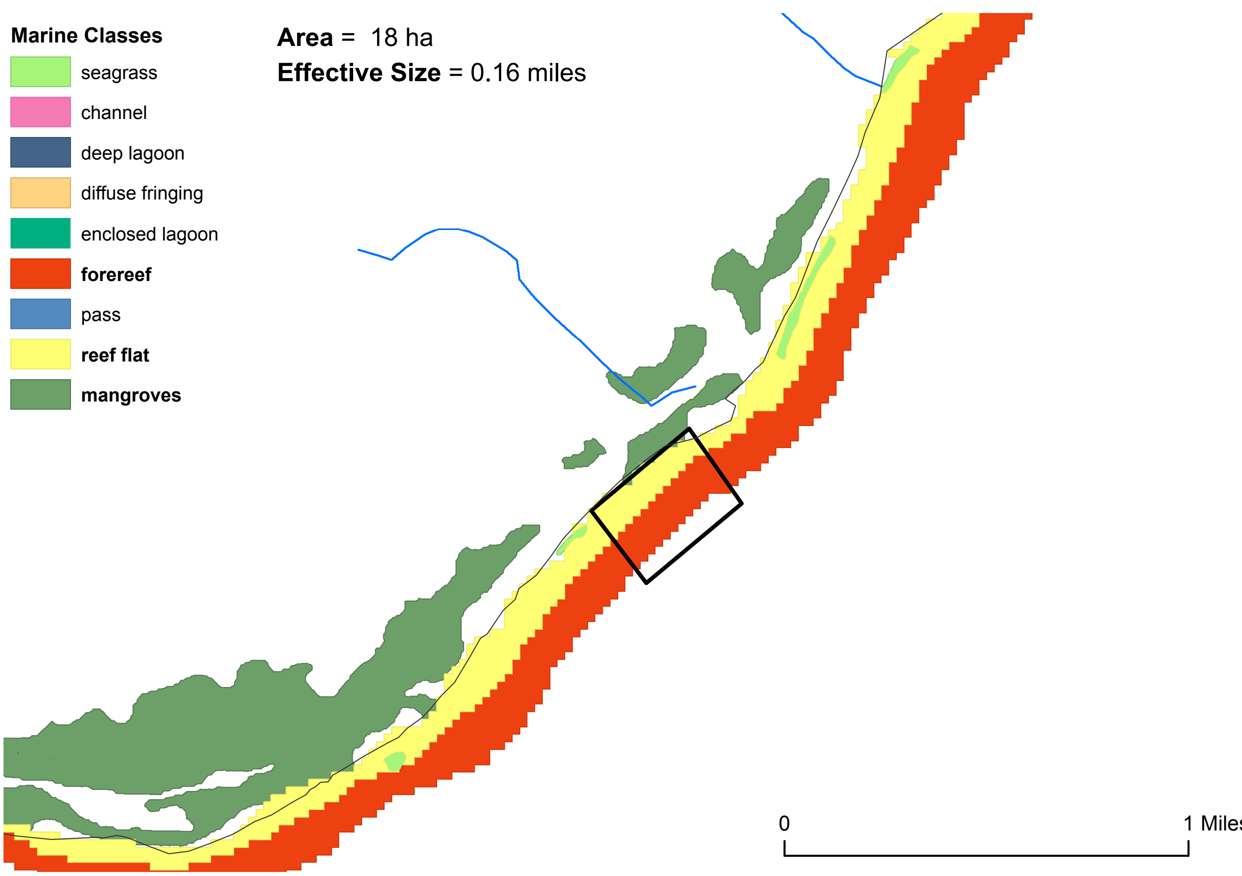
Malem Proposed Marine Conservation Area


Distance to mangroves = 0 miles


Distance to seagrass = 0.1 miles



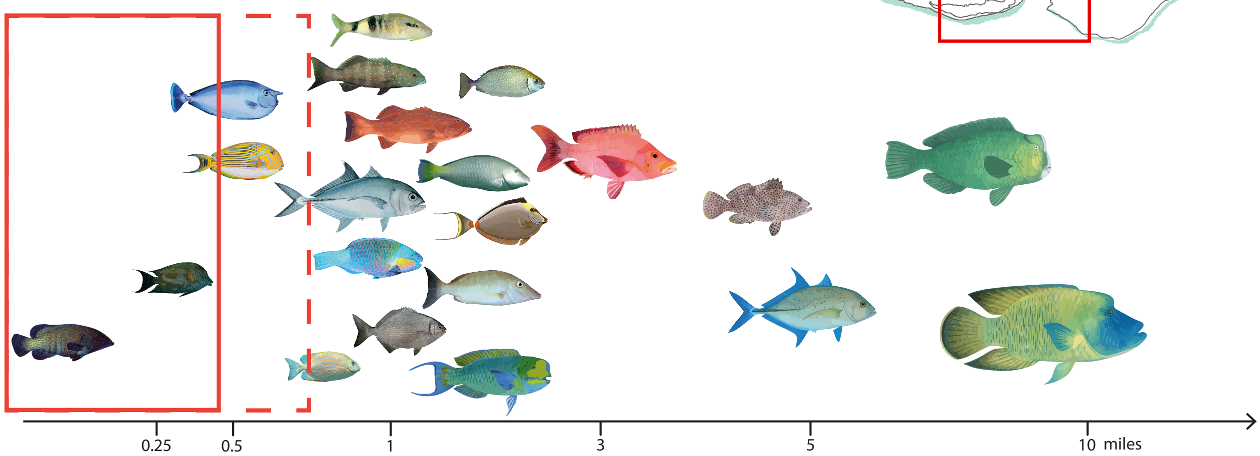


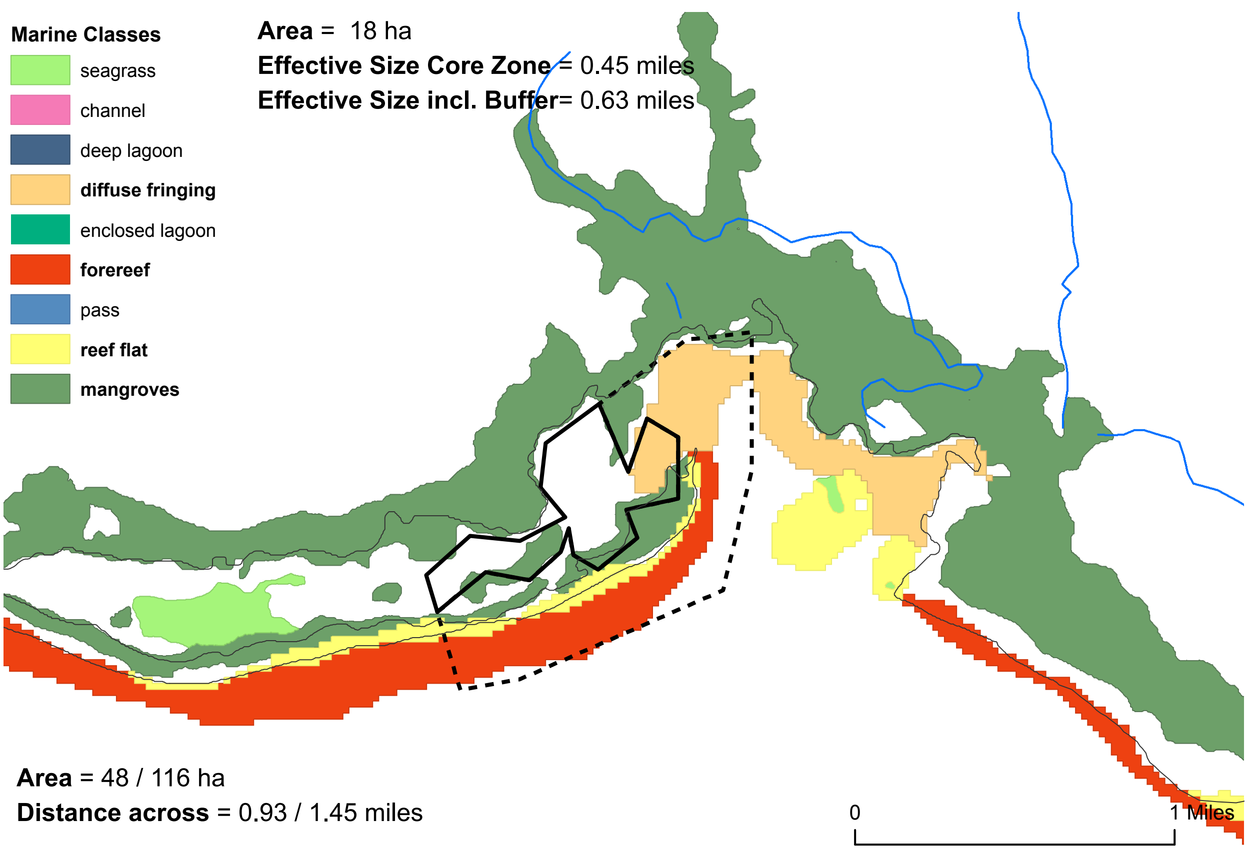


Utwe Biosphere Reserve

Distance to mangroves = 0 miles

Distance to seagrass = 0.5 miles





Recommendations by Municipality

This section summaries management recommendations that are particularly relevant to each of Kosrae's municipalities, which can be used (along with the MPA Scorecards above) in municipal or community level discussions.

Tafunsak

- The proposed Tafunsak marine conservation area is small and the protects channel only. Better protection would be afforded to more fish species if the boundaries were extended to include a larger extent and more habitat types.
- The (newly) proposed MPA in Walung would do a good job at protecting most coral reef associated habitats in Tafunsak's coastal barrier reef system, however more protection may be required for seagrass habitats (utilized by rabbitfishes and other species).
- The reef fish spawning aggregations identified are not within proposed MPAs. Reef fish spawning aggregations are especially vulnerable to overfishing, and for this reason are typically prioritized for inclusion in marine protected area networks. If it is not feasible to protect these locations with no-take areas, alternative management strategies might be implemented. These could include a ban on fishing during the peak spawning season for key species (this may require several short closures at monthly intervals, as some species appear to aggregate around the period of the new moon).
- Consideration could also be given to including the mangroves adjacent to the proposed Walung MPA and Yela Watershed conservation area, as these are underrepresented in Kosrae's PAN. Alternatively, other effective area-based management might be implemented to ensure sustainable use of the extensive mangrove areas in Tafunsak.

Lelu

- The Awane proposed MPA is in an area identified as having poor water circulation. Consideration should be given to whether protected area designation will help to overcome this threat, if complementary land use regulations can be imposed to improve water quality, or whether a more suitable (i.e. better quality) area might be protected instead.
- Forereef and reef flat habitats remain underrepresented in proposed MPAs on Kosrae's exposed reef system. Communities might be encouraged to consider whether modifications to the boundaries of proposed protected areas could be made to include some areas of these habitats.

Malem

- The proposed MPA does not incorporate the Mosral Reef, which was identified as a unique and special reef area. Malem should consider whether the unique values they attributed to the Mosral Reef might be threatened by continued resource extraction, or, conversely, conserved through its designation as a protected area.
- Forereef and reef flat habitats remain underrepresented in proposed MPAs on Kosrae's exposed reef system. Communities might be encouraged to consider whether modifications to the boundaries of proposed protected areas could be made to include some areas of these habitats.

Utwe

- Erosion and sedimentation were identified as threats within the Utwe Biosphere Reserve. Utwe should consider establishing complementary land use regulations to reduce these threats. These regulations could include protecting riparian buffers in the watershed.
- Forereef and reef flat habitats remain underrepresented in proposed MPAs on Kosrae's exposed reef system. Communities might be encouraged to consider whether modifications to the boundaries of proposed protected areas could be made to include some areas of these habitats.
- Consideration could also be given to including the mangroves adjacent to the Utwe Biosphere Reserve, as these are underrepresented in Kosrae's PAN. Alternatively, other effective area-based management might be implemented to ensure sustainable use of the extensive mangrove areas in Utwe.

Members of Walung community using an MPA Scorecard in discussions about the design of their proposed MPA. Upon realising that the proposed design would protect few of the fish species prioritized by members of the community, workshop participants proposed changes to the MPA boundaries.