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# PALAU'S NORTHERN REEF FISHERIES MANAGEMENT PLAN 2016

*"Together we can chart the course that will help our fishermen thrive today and our culture thrives for generations to come."*
—Rteruich Katsushi Skang, Chairman, NRFC

Prepared by The Nature Conservancy April 27, 2016

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***ACKNOWLEDGEMENTS***

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# EXECUTIVE SUMMARY

Palau's Northern Reefs form one of the country's largest coral reef complexes and include some of the most productive fishing grounds. For centuries, the Northern Reefs' fishery resources were relatively untapped due to the area's remote location. However, improved access and better fishing technology has led to an increase in fishing in the Northern Reefs by outside fishermen, particularly fishermen residing in Koror. Today, overfishing has led to a decline in fisheries resources that has been further exacerbated by a nationwide change from traditional subsistence fishing to commercial fishing, changes from a historic "reef assignment" system to an open-access fishery, and by other drivers such as:

1) economic development and tourism growth;
2) high per capita fish consumption compared to other regions in the Pacific;
3) high demand for reef fish at family events and local food markets;
4) access to advanced fishing gear that increases harvesting potential; and
5) market dynamics, such as a low price for fish, that lead to an increase in fishing.

To address the continued decline in the health of fisheries resources in the Northern Reefs, the fishermen and the governments of Kayangel and Ngarchelong engaged in a fisheries reform process that involved understanding the status of their fisheries, discussion on management and formulation of this fisheries management plan. The goals of the Kayangel and Ngarchelong State Governments, fishermen, and communities are to:

1) rebuild fish populations and improve ecosystem health to support long-term sustainable use of resources; and
2) ensure that the people of Ngarchelong and Kayangel have access to the resources they need and benefit directly from long-term stewardship.

The management approaches to achieve these goals are:

1) implementing fishing permit system to control access;
2) implement size limits to increase spawning biomass;
3) protect habitats to ensure life history for certain reef fish species; and
4) improve process for management and enforcement.

Left to Right: @ TNC; PIRC

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# 1.0 INTRODUCTION

## 1.1 PROBLEM STATEMENT

Palau's Northern Reefs form one of the country's largest coral reef complexes and include some of the most productive fishing grounds. This area includes parts of Kayangel and Ngarchelong States and extends from the northern tip of Babeldaob to Velasco Reef, incorporating Kayangel Atoll, Ngariuns Islet (with a large nesting population of megapode birds), and Ngaruangel and its islets (that provide nesting areas for seabirds and green turtles).

For centuries, the Northern Reefs' fishery resources were relatively untapped due to the area's remote location. However, improved access and better fishing technology has led to an increase in fishing in the Northern Reefs by outside fishermen, particularly fishermen residing in Koror. Today, overfishing has led to a decline in fisheries resources that has been further exacerbated by a nationwide change from traditional subsistence fishing to commercial fishing, changes from a historic "reef assignment" system to an open-access fishery, and by other drivers such as:

1) economic development and tourism growth;
2) high per capita fish consumption compared to other regions in the Pacific;
3) high demand for reef fish at family events and local food markets;
4) access to advanced fishing gear that increases harvesting potential; and
5) market dynamics, such as a low price for fish, that lead to an increase in fishing.

While fishing by individual fishermen is on the rise in the Northern Reefs, commercial fishing has had a different trajectory. The first introduction of commercial fishing in the area came in 1983 when the Palauan government, with grant aid from Japan, invested in major fisheries development such as icemakers, fishing boats, and fishing gear. Then the Palau Federation of Fishing Association and later Palau Fishing Authority began purchasing fish for local markets and export markets and soon there was more fish available than could be sold locally or exported out of Palau, leading to spoiled fish and causing concern among fishermen. Soon afterwards, the Hong Kong-based Live Reef Fish Trade began focusing on Palauan grouper, leading to the decline and eventual disappearance of grouper aggregations in some areas around Koror. Proponents of the industry tried to tap the remaining aggregations in the Northern Reefs, but the States of Kayangel and Ngarchelong denied them permission. This led to a *bul*, or traditional closure, of the eight reef channels in the Northern Reefs. While the reefs were spared from the Live Reef Fish Trade, fishermen from Koror and other states continued to poach in the Northern Reefs, and the number of fishermen steadily increased as fishing boats became larger and fishing technology became more accessible.

In response to this threat, Kayangel worked closely with The Nature Conservancy (TNC) to establish the 34.9 km.$^2$ Ngaruangel Nature Reserve in 1996 as the first Marine Protected Area (MPA) in the north. In 2000, Ngarchelong followed suit when it established Ebiil Channel Conservation Area to protect the grouper aggregation. Recognizing the benefits of this closure, Ngarchelong expanded the Ebiil Conservation Area in 2003 to cover approximately 19 km.$^2$ of reef channel and reefs. The success of these MPAs led to more than 30 new MPAs in Palau, representing over 1,685 km.$^2$ of shallow marine areas. In 2003, Palau passed the Palau Protected Areas Network (PAN) Act to institutionalize the management and funding of these sites through a sustainable finance mechanism called the "Green Fee," a $30 exit fee for all visitors to Palau.

Despite the success of the PAN and broad support for biodiversity conservation across Palau, there is a general concern that the country's fisheries are continuing to decline. These declines are likely the result of the continued fishing pressure and the limitations of using MPAs as the primary response to overfishing, since the MPA network that currently exists is not adequately designed or enforced in such a way as to reverse this decline. MPAs also need to be integrated with other non-spatial fishery management tools to be effective, which has not previously been the case. Other challenges also include a lack of adequate compliance and enforcement, a lack of scientific data to support fisheries policy and management strategies, the need for fishermen to participate more in fishery management, and the general lack of capacity for fisheries management at the national and state levels.

In response, TNC launched a pilot project in the Northern Reefs in 2013 in collaboration with the States of Kayangel and Ngarchelong, Palau International Coral Reef Center (PICRC), Palau Conservation Society (PCS), Bureau of Marine Resources (BMR), and the Palau Protected Areas Network Office (PANO), to test an integrated fisheries management approach to reform fisheries management and rebuild depleted fish stocks in Palau. Through an engagement with the fishermen and communities of Kayangel and Ngarchelong States, the collection of fisheries data (on species and lengths of catch) for key species revealed that more than 50% of fish being captured in the Northern Reefs were immature and had not had the chance to reproduce. This trend has slowly contributed to the continued decline in fish, despite efforts to establish protected areas and manage over 50% of coastal marine areas in Palau. By participating in these studies, fishermen in the Northern Reefs were able to see firsthand why their fish stocks are declining.

Recognizing they needed to take immediate action, fishermen, communities, and traditional and elected leaders from the two states made a commitment to work with the its government and NGO partners toward managing their fisheries and toward recovering their important fish stocks.

## 1.2 POLICY CONTEXT

In response to increasing pressure on marine resources in Palau, the Palau National Government enacted the Palau Marine Protection Act of 1994. The act mandated national regulation of certain species by size, seasonal closures, a ban on the use of scuba for spearfishing, established mesh size for nets, regulated export of certain species, etc. In 1996, recognizing the further decline in their marine resource, Kayangel State adopted Ngaruangel Reserve Act of 1996 establishing the Ngaruangel Nature Reserve. And in 2000, Ngarchelong State adopted an Act establishing the Ebiil Channel Conservation Areas, and in 2003, the boundaries were expanded to further protect declining fish resources. In addition, Palau established the Palau Protected Areas Network (PAN) Act in 2003 to provide a legal framework for establishing a system of protected areas throughout Palau and mandating the Palau National Government to establish a system to support implementation of the network. In 2008, the leadership of Ngarchelong through the Mengellakl Declaration, tasked the Governor of Ngarchelong to seek assistance and support from technical partners to address declining marine resources for Ngarchelong State. In 2012, both Kayangel and Ngarchelong States declared their territorial waters PAN sites, making the northern reefs the largest multi-use protected areas in the Palau main archipelago.

These policy efforts by the two northern states are in response to their fishermen and community members' concern for continued decline in their fisheries resources despite current conservation efforts in order to address the declining health of marine resources. The two states recognized the need to manage the Northern Reefs as one system to ensure effective management and enforcement to conserve and protect their resources. In 2013, Kayangel and Ngarchelong established a Cooperative Agreement between the two states for Sustainable Fisheries Management and PAN. This agreement demonstrated the shared concern by Northern Reef state leaders about the steady decline of reef fish, as confirmed and quantified by data-poor stock assessments conducted between 2013-2015 by Dr. Jeremy Prince (Prince et al. 2015) supported by TNC.

The two states made a joint commitment to:

- cooperate on establishing a sustainable fisheries management program;
- integrate fisheries management with PAN sites management;
- establish a joint monitoring, surveillance and enforcement program; and
- empower fishermen and communities to become active participants in fisheries management and be the main beneficiaries of sustainable harvest programs.

Further to these previous efforts, Kayangel and Ngarchelong States enacted legislations in 2015 known as Coastal Fisheries Management Act, namely Bill No: 15-16 and Bill No. 15-57, respectively. The legislations established a 3-year moratorium on 5 species of groupers, enhanced and clarified enforcement authority, and mandated the Governor to establish further regulations to protect and improve fisheries resources in the Northern Reefs. These legislations provide the basis for this Northern Reefs Fisheries Management Plan (FMP).

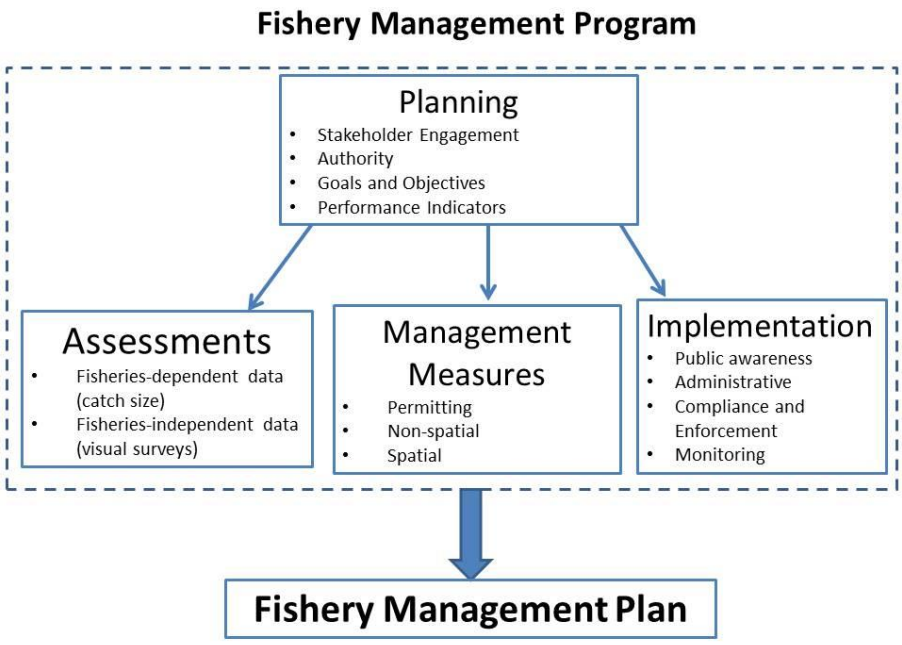
## 1.3 FISHERIES MANAGEMENT PROGRAM

A fishery management program describes the full range of activities that occur in an iterative process of planning, implementation, and adaptive management of fisheries (Figure 1). Specifically, a fishery management program includes elements such as:

- planning and establishing fishery management goals;
- developing a fisheries profile that includes assessing the status of important stocks and the ecosystem context in which the fishery is embedded;
- identifying management measures (spatial, non-spatial and others) that are most appropriate to the fishery context and designed to achieve the desired goals;
- implementing management measures including building capacity, raising awareness of fishery goals and status, and establishing a monitoring and surveillance program and enforcement capacity;
- monitoring of biological and socioeconomic indicators to ensure that goals are being met; and
- managing adaptively in a process that allows for changes in management measures based on changing conditions and goals.

The planning approach and fishery management goals are summarized below, while the remaining elements of the FMP are described in following chapters.

FIGURE 1. ELEMENT OF FISHERY MANAGEMENT PROGRAM



## 1.4 FISHERIES MANAGEMENT PLANNING

This Northern Reefs Fishery Management Plan (FMP) aims to document the fishery management goals for Ngarchelong and Kayangel States, the current understanding of the stock status, the management measures the communities aim to implement, how those management measures will be enforced and monitored, and how an adaptive management framework will be used to adjust management measures if goals are not being achieved.

The formulation of this FMP is guided by Kayangel and Ngarchelong Coastal Fisheries Management Act of 2015. The act mandated the Governors from their respective states to promulgate rules and regulations to manage fishing and activities within their respective state waters.

Following the passage of the act, the governors from the two states established their planning team with the task of recommending fisheries management rules and regulations for the Northern Reefs of Palau. The planning team members represented fishermen, women, businessman, community leaders, and other stakeholders from within their state. TNC and the PCS provided support for the planning team's discussions on the regulations and key technical support in formulating the regulations and in drafting this Fisheries Management Plan.

The planning team agreed that both teams from the two states will work together to ensure similar management strategies will be applied to their states. The team agreed to outline the rules and regulations and to agree on the details before engaging with their communities for feedback, with the eventual goal of finalizing and submitting the proposed draft rules and regulations to their respective governors.

## 1.5 GOALS AND OBJECTIVES OF THE NORTHERN REEFS FISHERIES MANAGEMENT PLAN (FMP)

The goals of the Kayangel and Ngarchelong State Governments, fishermen and communities are to:

1) rebuild fish populations and improve ecosystem health to support long-term sustainable use of the resources; and
2) ensure that the people of Ngarchelong and Kayangel have access to the resources they need and benefit directly from long-term stewardship.

The objectives of management are to:

1) improve capacity for implementation of management;
2) sustain awareness and support from the communities for management;
3) provide data to inform adaptive management; and
4) provide access for thriving fisheries to support communities needs and livelihoods.

# 2.0 NORTHERN REEFS FISHERIES PROFILE

## 2.1 GEOGRAPHIC CONTEXT OF THE NORTHERN REEFS

The Northern Reefs of Palau includes the marine area north of the Babeldaob Peninsula extending to Velasco Reef (a 20-mile-long submerged reef system at the northern tip of the Palau archipelago with a relatively untapped fishery) (Figure 2). The marine area encompasses major reefs, channels, and passage systems that are known fish spawning aggregations sites. It also includes Kayangel atoll and its islets. Ngariuns islet hosts the largest colony of the endangered megapode bird in Palau. Ngaruangel islet is home to nesting seabird colonies as well as green turtle nesting. These marine resources from low water mark up to 12 miles offshore come under the ownership and management of Ngarchelong and Kayangel States.

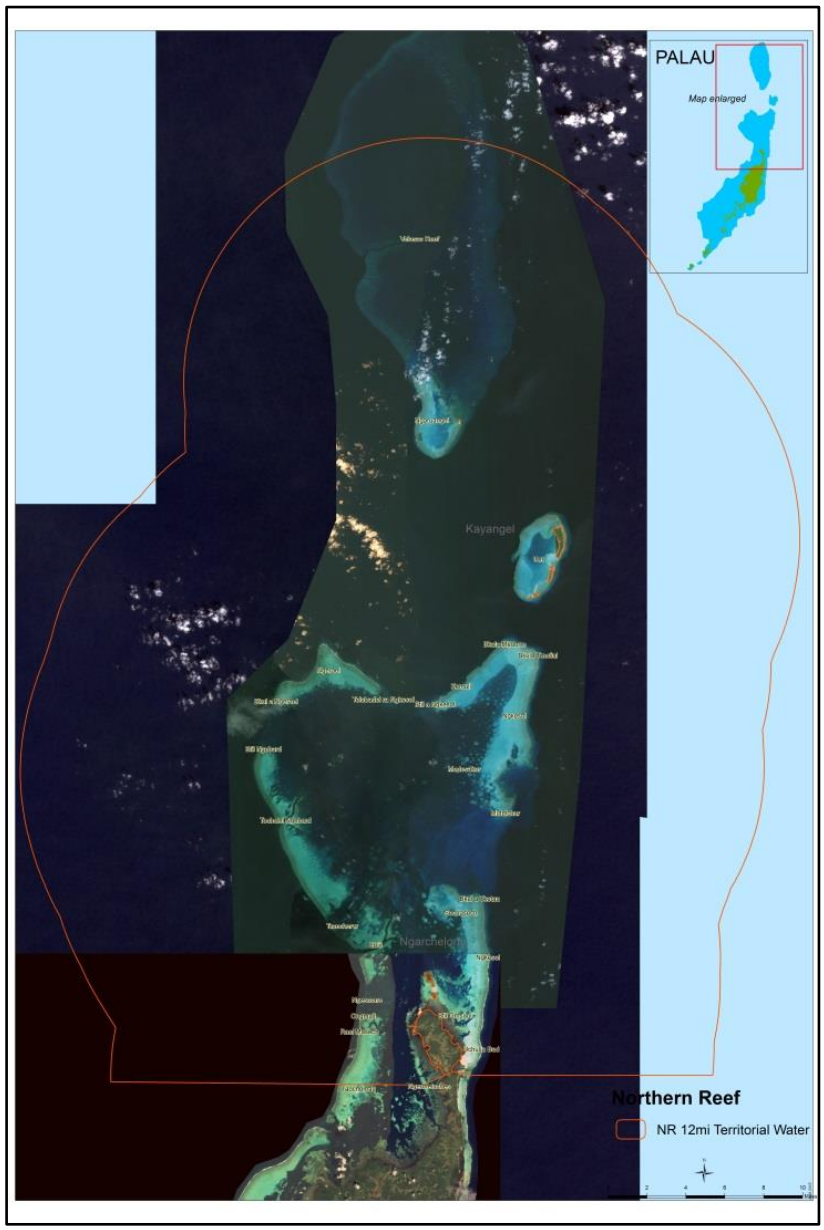



**FIGURE 2.** Northern Reefs of Palau. Red line indicates 12-mile territorial water boundary.

## 2.2 NORTHERN REEFS FISHERIES

In 1983, the Palau government, with grant aid from Japan, invested in major fisheries development, which included support facilities throughout Palau, such as icemakers, fishing boats, and fishing gears. Then Palau Federation of Fishing Association and later Palau Fishing Authority based in Koror began purchasing fish for local markets and export markets. There were more fish than can be sold or exported due to limited local demand and limited ability for export to overseas markets. Some of the fish ended up in freezers, losing market value, and some were donated to schools, hospital, and prison due to lack of storage space or dumped at sea due to spoilage.

Eventually fishing moved off-shore and the Secretariat of the Pacific Community (SPC) provided master fishermen to train local fishermen to fish outside the reefs for deep water species and small pelagic species. A Live Reef Food Fish Trade fishery was also initiated (based out of Hong Kong) that targeted groupers, wrasse, and coral trout, including their major fish spawning aggregation sites. It was the communities of Kayangel and Ngarchelong that raised concerns about the wasteful fishing and the lack of respect for traditional fishing practices and traditional boundaries.

The establishment of four fishing ports at strategic locations (north, east, west, and south of main Palau islands) throughout Palau was meant to encourage off-shore fishing. However, fishing for off-shore species did not materialize as planned, but the facilities continued to support strong fishing efforts for reef associated species. When fishing by communities could not provide enough fish to keep the facilities operating and the fishery cooperative became inactive, organized fishing ceased for the most part by the communities in the Northern Reefs. Fisheries facilities continued to support community development activities and some sport fishing as well as the fledgling diving activities.

With cessation of organized commercial fishing by communities in the northern villages, fishing pressure continued from fishermen from out-of-community residents, residing in Koror, who could afford high fuel cost and access to markets. It was not until the communities of Kayangel and Ngarchelong declaration of a traditional "*bul*" for the spawning channels in 1994 that some protection for northern fish stocks was initiated. While it appeared effective initially, it turned out to be insufficient in the long run. At about the same time, with the knowledge from fishermen, the Palau Marine Protection Act of 1994 was enacted. The act puts restrictions on fishing gear, species restrictions, seasonal closures, and ban exports of certain species.

## 2.3. FISHERIES SCIENCE CONTEXT

### OVERFISHING / SUSTAINABLE YIELD / OVERFISHED

The objectives of fishery management include maintaining fish stocks at levels that uphold ecosystem integrity and ensuring that harvested stocks have limited probability of collapse, while maximizing fishing opportunities for permitted fishermen. In order to accomplish these objectives, fishery management regulations must limit fishing pressure to rates that are consistent with these targets. Understanding the relationship between fishing pressure and stock productivity is therefore paramount. The sustainability of a fish stock is directly related to the species ability to replace itself under different rates of fishing mortality and natural mortality (M). The fishing mortality rate (F) is calculated as the number of animals removed in a given time period relative to the number of animals vulnerable to harvest at that time period. When fishing mortality occurs at a rate that allows the stock to maximize the population growth rate, the amount of animals removed at that level is known as ***maximum sustainable yield (MSY)***. MSY can otherwise be defined as the maximum catch that can be sustained over the long term.

When the number of animals being removed from a stock is too high, it is known as ***overfishing***. Overfishing for short periods of time results in ***growth overfishing***, limiting the ability of the fish stock to provide maximum yields to the fishery. If growth overfishing continues, compromising the ability of the stock to replace itself, ***recruitment overfishing*** occurs**.** Left unmanaged, recruitment overfishing can lead to the collapse of the stock. When a stock has been fished to a point at which recruitment has been compromised, the stock is considered to be ***overfished***. ***Ecosystem overfishing*** occurs when one or more key species are harvested beyond the ability of the ecosystem to maintain key functions, thus threatening the overall health of the system.

Length frequency distributions taken from a fishery dependent or independent survey can provide valuable insight into the status of the fish stock and fishing pressure. A length frequency distribution represents the summation of individual length measurements at every size category measured. ***Spawning potential ratio (SPR)*** is a measure of the sustainability of fishing pressure. SPR is defined as the reproductive output of a fished cohort relative to the reproductive output of that same cohort of animals in an unfished state. SPR can be estimated through interpreting the size structure of the stock as well as basic biological information such as the length at reproductive maturity. The size structure of the catch is directly related to the SPR of the stock, assuming the data are non-biased and representative of the entire stock.

The figures below (Mous and Pet 2014) depict length frequency distributions from a hypothetical fishery that targets juvenile fish (Figure 3), and a fishery that targets reproductively mature fish (Figure 4). Figure 3 represents a fishery that would demonstrate low SPR, while Figure 4 represents a fishery with a relatively high SPR.

Figure 5 shows the relationship between SPR and the fishing mortality rate or harvest rate. When fishing pressure is low, the SPR is high because very few animals have been removed from the population. As fishing mortality increases, SPR gets lower due to removals of reproductive animals from the stock. Generic SPR reference points have been developed through meta-analysis of quantitatively assessed fisheries. It is generally accepted that maintaining fish stocks at an SPR of 40% (SPR40), indicating that a cohort is producing 40% of its unfished potential, approximates the rate of fishing that would achieve MSY. This is often considered a target reference point for fisheries management (Mace and Sissenwine 1993). SPR20 is a proxy for the rate of fishing that would impair

recruitment rates indicating severe overfishing. This is often considered a limit reference point. It should be noted that these generic 'rule of thumb' reference points are approximations and should be considered temporary stopgaps until further information on the productivity of the fishery can be elucidated.

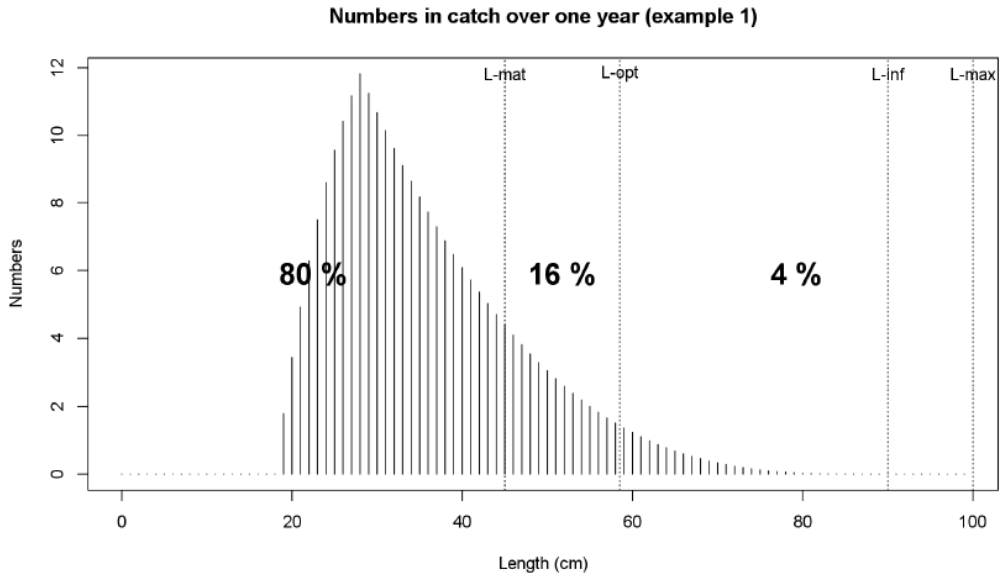



**FIGURE** ypothetical example of a length frequency distribution from the catch of a fishery with low SPR. This fishery harvests primarily individuals below the length at reproductive maturity (L-mat); such a fish stock would have a low SPR and likely below a target replacement level (e.g. 20%). Figure borrowed from Mous and Pet 2015.

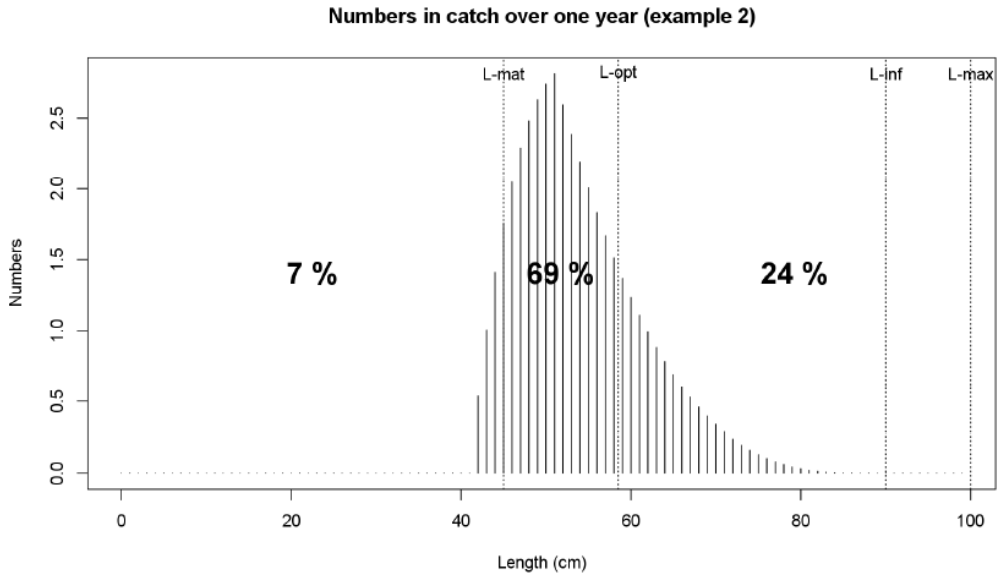



**FIGURE 4.** Hypothetical example of a length frequency distribution from the catch of a fishery with high SPR. This fishery harvests primarily individuals above the length at reproductive maturity (L-mat). Such a fish stock would have a high SPR, likely above a target replacement level (e.g. 20%). Figure borrowed from Mous and Pet 2015.

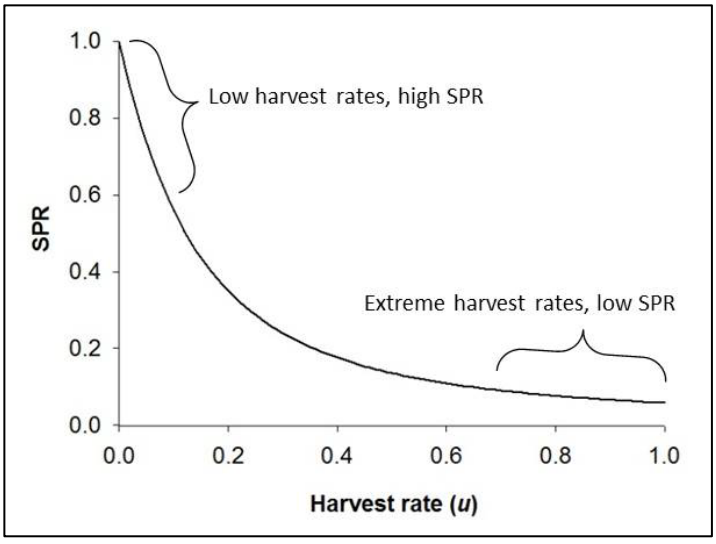



**FIGURE 5.** The relationship between Spawning Potential Ratio (SPR) and the fishing mortality rate or harvest rate. Figure borrowed from Mous and Pet 2015.

## MECHANISMS TO MAINTAIN SUSTAINABLE FISHING

There are a variety of mechanisms that can be used to maintain sustainable fishing:

*Minimum size limits*: A predetermined size at which a fish is legally allowed to be harvested. Typically, minimum size limits are specified in terms of the length or width (e.g. crabs) of an animal and are set at levels that ensure individuals have an opportunity to spawn at least once before being vulnerable to the fishery. Alternatively, size limits can be set at levels that specify a predetermined level of spawning potential, known as the Spawning Potential Ratio (SPR).

*Spatial closures:* A spatial closure is a geographic area that is off limits to particular types of fishing. A no-take zone is off limits to all types of fishing. Other types of spatial closures may include areas set as off limits to particular categories of fishermen or gear (e.g. commercial trap fishing) or areas off limits to fishing of certain types of species.

*Seasonal closures*: A seasonal closure is a ban on fishing during certain times of the year or during certain periods of the month (e.g. before and after a new or full moon). Seasonal closures can be used to limit overall fishing mortality as well as to protect spawning aggregations of vulnerable species from harvest.

*Species bans*: A species ban is a complete fishing restriction for a particular species. Such bans are implemented when there is reason to believe that the stock is overfished and requires considerable rebuilding before it is capable of providing surplus production to a fishery without compromising the sustainability of the stock.

*Sex-based regulations:* Sex-based regulations are those regulations that limit the harvest of a particular sex. Typically, such bans are implemented for females of the stock to protect adequate reproductive potential. Alternatively, sex-specific bans can be implemented for egg-bearing females for similar purposes.

*Catch-based regulations*: Catch-based regulations limit the amount of harvest available to individual fishermen, specific permit holders or the entire fishery. Usually such restrictions place a cap on the number of pounds available for an individual or the entire fishery to harvest in a given time period. Such restrictions require consistent catch accounting to determine whether the caps are being met.

## FISHERY MANAGEMENT REFERENCE POINTS AND HARVEST CONTROL RULES

Fishery management systems require managers to evaluate information and readjust decisions on a regular basis in order to ensure that targets and objectives of management are being met. These may include social, economic, and biological objectives. A logical framework for making adjustments to management measures is through a system of harvest control rules. A ***harvest control rule*** is an objective decision making process that interprets the status of a measurable ***indicator*** relative to a predetermined ***reference point*** and makes an adjustment to the management measure based on the relationship between the indicator and the reference point (Figure 6).

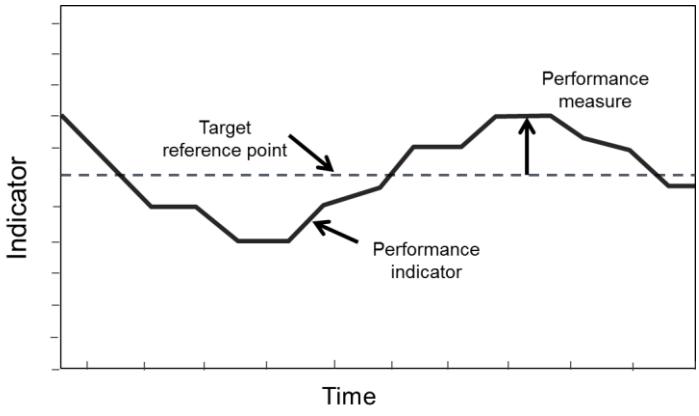



**FIGURE 6.** The relationship between an indicator and a reference point is known as a performance measure. Depending on this relationship, management measures can be adjusted up or down. Such a framework for decision making is known as a harvest control rule.

Indicators that may be important to measure are discussed in the data and monitoring section (5.1) and may include density estimates, SPR metrics, catch rates, total landings, and others. Possible management measures that may be adjusted could include size limits, length of species bans, seasonal closure windows, number of permits, or total pounds available for harvest to an individual or to the fishery (Table 1). The appropriate fisheries management measure to adjust, and how much it should be adjusted in different situations, will depend on the target species, likelihood of compliance, social and political feasibility, capacity for enforcement, and data availability. It is important for stakeholders and managers to agree on harvest control rules before any new management decisions need to be made. This can help improve compliance by ensuring management responses are objective, consistent, transparent, and appropriate.

**TABLE 1.** Types of indicators and management measures that could be considered for a harvest control rule.

| TYPES OF INDICATORS | ASSOCIATED REFERENCE POINTS |
|---|---|
| Spawning Potential Ratio (SPR) | SPR 20%; SPR 40% |
| % of catch > than size of maturity | 90%, 100% |
| Total landings | Historical Average; Predetermined amount |
| Catch Per Unit Effort (CPUE) | Fraction of Historical Maximum;<br>Average over a selected period of time |
| Transect density/abundance estimates | Baseline Averages;<br>Baseline minimum or maximums |

**TYPES OF MANAGEMENT MEASURES TO ADJUST**

- Size limits
- Season closures
- Length of species bans
- Number of permits available for particular permit categories
- Total pounds available for individual fishermen, per permit category or the entire fishery

FIGURE 7. PHOTO SHOWING FISH GONADS BEING MEASURED TO ESTIMATE SIZE AT MATURITY

## 2.4 EXISTING MONITORING DATA

Like many small scale coastal fisheries, Palau lacks adequate fisheries monitoring data to better understand the impact of fishing on fisheries as well as trends in fisheries use. There have been various surveys focused on fish and less on fisheries. PICRC probably has the most extensive data on underwater fish surveys in Palau commencing in 2001. Golbuu and Friedlander (2010) provided results of grouper studies at two protected spawning aggregations sites. The study showed positive effects of protection on abundance of the grouper as compared to similar known aggregations sites that has continued to experience fishing pressure. The PICRC study has included fish as an indicator as part of coral reef monitoring FIGprogram and MPA assessment studies. The results show there are more fish in no-take areas compared to areas open for fishing, and marketing landing bases on invoices for fish sold at Happy Fish Market (BMR unpublished data).

In 2009, Secretariat of Pacific Community (SPC) conducted fisheries household survey and a limited fisheries survey focused on finfish and invertebrates in 4 states in Palau. The data showed the relative importance of fishing as an income source with less than 10% of fishermen relying on fishing as a primary source of income. The study further showed the importance of fish for local consumption as the highest rate compared to other Pacific Islands. In 2011, Ebiil Society, Inc. began collecting catch data by weight at Ollei Port. The catch data showed a trend in fishing by season, location, and for purpose. The results indicate that customary obligation drives the increase in volume of fish caught/fishing trip.

In 2012, TNC along with Dr. Jeremy Prince in collaboration with fishermen from Kayangel, began a study to evaluate the status of the fishery in the Northern Reefs of Palau using macroscopic analysis of reproductive organs to determine the size of maturity for various species. The results showed that most fish being captured from the fishery were spawning below their 20% spawning potential ratio (SPR), the minimum required biological reference point to maintain their population (Prince et al. 2015). The intensity of fishing pressure was relatively high in that fishermen were beginning to catch fish before they had enough bread, which was contributing to continued decline in the fishery.

In 2014, in collaboration with PICRC and BMR, data collection at Happy Fish Market using stereo photo was established to collect species and size frequency data. The data collection is ongoing. In 2015, in collaboration with PICRC, landing

data at Ollei dock continued, and a stock assessment survey using stereo video was conducted. The stock assessment results showed the size structure (length of fish) was truncated over time and fish were generally smaller in fished areas compared to no-take areas (Linfield et al. 2015). This result reinforced what has been previously documented from the fishermen's catch.

In addition to local knowledge, some of the data sources used for marine spatial planning and designing fishery management recommendations included:

- habitat maps (Northern Reefs habitats from the southern part of Ngaruangel Reef to Ngarchelong were mapped by NOAA by classifying 2008 satellite data from the IKONOS sensor);
- data on the species composition and size structure of catch from the Northern Reefs, as well as size at maturity and other information (Prince et al. 2015);
- maps of fish spawning aggregation sites that primarily occur in channels and at reef promontories;
- data on the biomass and size structure of fish populations in the Northern Reefs (Lindfield 2015);
- maps of fishing grounds that were developed through interviews and participatory mapping (Victor 2016); and
- models and maps of coral reef fisheries pressure, current standing stock, and potential standing stock if fisheries management were improved (e.g. through the establishment of no-take areas: Harborne 2016).

## 2.5 CURRENT UNDERSTANDING OF FISH STOCK STATUS

Some of the first observations on the status of fish stocks in Palau originate in the writings of Johannes (1981) who worked with fishing communities to identify species of concern, as well as document the possible reasons for declining fish stocks. Declines were attributed to heavy fishing pressure, destructive fishing practices, and illegal fishing (Johannes 1991). Throughout the 1970s and 1980s the increased demand for fish to supply export markets as well as the domestic tourism industry in Palau led to increased catches, increased effort (e.g. bigger boats and engines), as well as a higher standard of living for many fishermen (Johannes 1991). Preston estimated the total seafood catch of Palau to be 1700 tons per year (Preston 1990) in and around 1990.

In 1994, Kitalong and Dalziell published results of an examination of length frequency data from commercial landings in Koror during the years 1990-1991.The length-based analyses using the software application Elefan revealed that the reef fish in the commercial landings were moderately exploited and nearing the optimal size at which maximum yields could be obtained. The exception to this finding was Humphead Wrasse or Maml (*Cheilinus undulatus*), which was found to be undergoing overfishing.

**FIGURE 8. FISH BEING MEASURED FOR LENGTH AND GONAD ASSESSMENT**

In the early 2000s surveys of fishermen and their perception of the status of stocks found that 87% of households in Palau had someone that fished, either for subsistence or for commercial sale (PICRC, unpublished data). 31% of fishers perceived the inshore stocks of Palau to be harvested at unsustainable rates, and the size of the catch was estimated to be three times smaller than in the previous decade (A. Kitalong, pers. comm.). Graham (2001) further documented that several large scale export fishing companies working in the Northern Reefs stopped operations in the late 1990s and early 2000s due to declines in available product.

Beginning in 2011, a fishermen led data collection effort was initiated in the Northern Reefs to collect length frequencies of landed reef fish species. Of the roughly 106 landed species in the region, data was collected on the top 15 species on a weekly basis at the port of Ollei (Prince et al. 2015). As of August 2014, 6852 individual measurements had been taken. In addition to this work, in 2014 and 2015 SCUBA surveys led by PICRC were conducted to document fishery independent length frequency distributions using underwater stereo-video techniques (Lindfield 2015).

In 2015, Prince (et al. 2015) published a comprehensive assessment of the status of twelve Palauan reef fish. Results from Prince (et al. 2015) suggest that the spawning potential ratio (SPR) of eight commercially important species were below limit reference points associated with recruitment overfishing (e.g. < $SPR_{20}$). The additional four species of fish were found to be below the target reference point of $SPR_{40}$, but above the limit reference point of $SPR_{20}$, indicating moderately high concern for the sustainability of current fishing pressure. SPR results (Prince et al. 2015) can be found in Table 2.

**TABLE 2.** Estimates of SPR, F/M and selectivity ($SL_{50}$, $SL_{95}$) for 12 species of reef fish from the Northern Reefs of Palau. Figure borrowed from Prince et al. 2015. Estimates of F/M should be disregarded in this instance as the methodology used for this calculation failed to account for differences in selectivity across sizes of fish.

Point estimates of spawning potential (SPR), fishing pressure (*F/M*) and selectivity ($SL_{95\%}$, $SL_{50\%}$) derived with 'best' estimate parameters from the length-based assessment of 12 Indo-Pacific reef species of reef fish in Palau.

| **Species** | **SPR (%)** | ***F/M*** | **$SL_{50\%}$ (mm)** | **$SL_{95\%}$ (mm)** |
|---|---|---|---|---|
| Lutjanus gibbus | 0.10 | 4.1 | 224 | 252 |
| Lutjanus bohar | 0.27 | 1.4 | 265 | 347 |
| Lethrinus rubrioper culatus | 0.23 | 3.9 | 239 | 279 |
| Lethrinus olivaceus | 0.10 | 5+ | 465 | 608 |
| Lethrinus xanthochilus | 0.13 | 5+ | 351 | 440 |
| Lethrinus obsoletus | 0.03 | 5+ | 260 | 325 |
| Plectropomus areolatus | 0.05 | 5+ | 480 | 571 |
| Pelectropomus leoparadus | 0.01 | 5+ | 334 | 419 |
| Variola louti | 0.20 | 1.4 | 203 | 266 |
| Scarus rubroviolaceus | 0.07 | 5+ | 355 | 454 |
| Chlarurus micrarhinos | 0.21 | 3.1 | 333 | 406 |
| Hipposcarus longiceps | 0.05 | 5+ | 276 | 313 |

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# 3.0 FISHERIES MANAGEMENT MEASURES

Three main types of fishery management measures are recommended in the Northern Reefs FMP:

- *Permitting measures:* to track fishing and other activities, promote local access, limit access of non-residents, and generate revenues to recover administrative costs;
- *Non-spatial management measures:* such as bans on certain species, minimum size limits, seasonal/temporal closures to promote rebuilding of depleted stocks; and
- *Spatial management measures:* a comprehensive zoning scheme that includes fully-protected no-take zones, limited use areas, and multi-use areas to promote rebuilding of fish stocks and ecosystem protection, as well as to limit the impacts of human activities to certain areas.

## 3.1 PERMITTING MEASURES

Protection and sustainable use of the marine resources of Ngarchelong and Kayangel for the benefit of the local communities can be facilitated by measures to track access and activities of resources users, and to limit access for activities that are inconsistent with the overarching management goals. A permitting scheme, whereby all resource users are required to have the appropriate permit for the activities they are undertaking is a proven method of tracking resource use. Limiting the number of permits approved for some activities (e.g. commercial fishing) can also be an effective measure to control fishing effort, if adequately enforced or compliance ensured through heavy penalties. Permit fees can also be used to generate revenue to cover administrative and enforcement costs.

### FISHING PERMITS / LICENSES / FEES

A permitting approach and fee schedule were developed with the intention of supporting effective enforcement (and generating some revenue to recover administrative costs) by requiring permits for different types of users and activities (Table 3). The people of Kayangel State depend on the Northern Reef, especially the marine resources within the state's waters, for their livelihood and sustenance. The rapid growth of Palau's dependence on fisheries as an income source and open access to the Northern Reefs has contributed to the decline in fisheries and is threatening the livelihoods and economic wellbeing of the people of the Kayangel people. Due to the compelling state interest in protecting and managing the Northern Reef, the people of Kayangel State have determined it is necessary to manage activities within the Northern Reef through an adequate permitting and licensing system as described below.

Generally, the permit conditions and fees favor local residents of Kayangel and Ngarchelong. Some types of permits, such as Guest Fishing permits will be limited in number to reduce fishing impacts by non-residents. Upon adoption of state Coastal Fishing Rules & Regulations, there shall be a three (3) month grace period to allow for public education regarding the Regulations. Upon expiration of the grace period, full enforcement of the Regulations shall be implemented.

It was decided it was not necessary to have a separate permit for customary use, because a community member would still be able to meet customary obligations under permits issued for subsistence, or community members can purchase fish from commercial fishers. For example, when a customary event occurs, a group of fishermen usually goes up to catch the fish and therefore, each subsistence fisherman has an allowable quota of 100 lbs/day, and with each fishing trip they are able to bring in enough fish to meet the customary needs.

*Subsistence Fishing Permits*: A person must have a subsistence fishing permit in order to fish within state waters for sustenance and artisanal (local *makit*) purposes. Subsistence fishing is fishing to provide fish for personal consumption, giving away to friends and relatives, and meeting cultural obligations. The subsistence permit also covers Makit – fishing to sell at local markets, as raw or processed, and/or fishing for hire, i.e. when a relative or someone asks for fish and is willing to pay for the fish. Usually fish are used for personal consumption or to meet cultural obligations. The Permit is only available to Kayangel and Ngarchelong citizens with a 100 lbs/person/day catch limit. Large subsistence fishing zones have been identified close to major villages to ensure easy access.

*Commercial Fishing Permits*: A person must have a commercial fishing permit in order to fish within state waters for commercial fishing purposes. Commercial fishing is fishing with the primary purpose of selling the catch. This permit is only available to Kayangel and Ngarchelong citizens, and fishing under this permit is only allowed at designated zones. Applicants must be fishing with a person or business that has already been issued a Commercial Fishing License in accordance with these Regulations. Such person or business holding the commercial fishing license must be listed on the application. The Applicant is limited to commercially fish with only one person or one business with a Commercial Fishing License.

*Guest Fishing Permit:* A person must have a guest fishing permit in order to fish within state waters as a guest of subsistence or commercial fishing permit holder. Palauans who are non-citizens of Kayangel and Ngarchelong must be accompanied by a permitted citizen The Guest Fishing Permit allows for a 25lbs/person/day catch limit and a maximum of 7 fishing trips/year.

*Recreational Fishing Permit – Fishing Derby Permit:* A boat or vessel must have a Fishing Derby Permit in order to participate in a fishing derby within state waters. All persons onboard the boat or vessel participating in the fishing derby must hold Subsistence or Commercial or Guest Fishing Permits.

*Recreational Fishing Permit – Catch & Release Permit:* A person must have a Catch & Release Fishing Permit in order to participate in Catch & Release recreational fishing within the state waters. A Recreational Fishing Permit holder that is participating in Catch & Release must not keep any fish caught in no-take zones in Ngarchelong and Kayangel State waters (but may keep fish caught in other zones) and are restricted to rod and reel fishing gears.

*Aquaculture Permits*: A person must have an Aquaculture Permit in order to establish an aquaculture farm within the state. Aquaculture activities (e.g. clam, crab, or fish farming) are only allowed at sites to be designated by the states for those activities; sites to be determined after further consultation. The Aquaculture Permits include a water use rights fee of $100. Aquaculture operations that will require animal feeds should be conducted using Best Management Practices and will be overseen in partnership with the Northern Reef Cooperative, Bureau of Marine Resources, and Environmental Quality Protection Board (EQPB). For aquaculture operations that will impact water quality, EQPB already has a permitting process to follow.

*Commercial Fishing License:* Every person or business that fishes within the waters of both Ngarchelong and Kayangel State and for the purpose of commercial fishing must first be issued a commercial fishing license by the state governments. All fishermen employed under the Commercial Fishing License must hold a Commercial Fishing Permit. Commercial Fishing Licenses are limited to three licenses per year to citizens of both states only.

*Boat Licenses*: Every motorboat owned or operated in Kayangel and Ngarchelong State must be registered with State Offices. There is a rebuttable presumption that a motorboat that is being anchored, docked, or moored in either state

for a period of 10 days is owned by a resident of that state and must be registered by the state. Monitoring and enforcement is also supported by requiring all boats to have a boat license, carry safety equipment, and fly flags to indicate the type of activity they are engaged in. The national regulations on boat licensing and fees will be fully incorporated into the FMP.

**TABLE 3. PROPOSED NORTHERN REEFS PERMITTING AND FEE SCHEDULE**

**PERMITTING MANAGEMENT MEASURES**

| PROPOSED PERMITS | DESCRIPTION | PROJECTED BENEFITS | PROPOSED FEE | MEASURABLE INDICATORS | REVIEW/ ADJUSTMENT PROCESS |
|---|---|---|---|---|---|
| Boat Registry | All boats require license under state regulations, w/fee determined by horsepower; requires use of flag for different activities | Safety, improved enforcement, covers administrative costs | As per state regulations | • Number of violations over time<br>• Ease of enforcement and tracking of activities by spatial zone | Review and adjust in 3 years |
| Subsistence Fishing Permit | A person must have a Subsistence Fishing Permit in order to fish within state waters for sustenance and artisanal (local *makit*) purposes | Control access, improve enforcement, retain local benefits | $10/person/year | • Public acceptance (survey before/after)<br>• Number of violations declining over time<br>• Trends in fishing activity and catch by port | • Phase in w/3-month grace period and graduated sanctions<br>• Review and adjusted in 3 years |
| Guest Fishing Permit | Guest Palauan who is non-citizen of Kayangel or Ngarchelong, fishing for food with limit of up to 25 lbs/day per person | Control access, improve enforcement, retain local benefits, and cover administrative costs | $5/day, up to 7trips/year | • Public acceptance (survey before/after);<br>• Number of violations declining over time<br>• Trends in fishing activity and catch by port | • Phase in w/3-month grace period and graduated sanctions<br>• Review and adjusted in 3 years |
| Commercial Fishing Permit | A person must have a Commercial Fishing Permit in order to fish within state waters for commercial fishing purposes - fishing for primary purpose of selling | Control access; improve enforcement; retain local benefits; cover administrative costs | Annual fee $25/person for Palauans and $50/person for non-Palauans in Ngarchelong State. $100.00/person Palauan & Non-Palauan | • Public acceptance (survey before/after);<br>• Number of violations declining over time<br>• Trends in fishing activity and catch by port | Review and adjust in 3 years |
| Recreational Fishing Permit – Fishing Derby | Boat or vessel must have a Fishing Derby Permit in order to participate in a fishing derby within state waters | • Revenue generation to cover administrative costs<br>• Reduced take by non-citizens | $50/boat/derby | • Number of violations declining over time<br>• Trends in tourism activities and impacts over time | Review and adjust in 3 years |
| Recreational Fishing Permit – Catch & Release | A person must have a Catch & Release Fishing Permit in order to participate in Catch & Release recreational fishing within the state waters. A Recreational Fishing Permit holder that is participating in Catch & Release must not keep any fish caught in no-take zones in Ngarchelong and Kayangel State waters (but may keep on fish caught in other zones) and are restricted to rod and reel fishing gears. | • Revenue generation to cover administrative costs<br>• Reduced take by non-citizens | $30/person for three days for Kayangel State and $30.00/person/day for Ngarchelong State | • Number of violations declining over time<br>• Trends in tourism activities and impacts over time | Review and adjust in 3 years |
| Aquaculture (fish, crab, giant clam) Permit | A person must have an Aquaculture Permit in order to establish an aquaculture farm within the state | • Recover administrative costs<br>• Possible spawning and out planting benefits to wild stocks<br>• Alternative livelihoods | Annual fee of $100 if applicant is not generating revenue and $200 if applicant is generating revenue | Work with Environment Agency to site appropriately and monitor impacts over time | Review and adjust in 3 years |
| Commercial Fishing License | Every person or business that fishes within the waters of Ngarchelong and Kayangel State for the purpose of commercial fishing must first be issued a Commercial Fishing License by the state | • Control access<br>• Improve enforcement<br>• Retain local benefits<br>• Cover admin costs | Annual fee $500 | • Public acceptance (survey before/after)<br>• Number of violations declining over time<br>• Trends in fishing activity and catch by port | Review and adjust in 3 years |

## 3.2 NON-SPATIAL MANAGEMENT MEASURES

A set of proposed non-spatial management measures to control harvest is proposed, in addition to the existing national fishery regulations

### 3.2.1 EXISTING NON-SPATIAL MANAGEMENT MEASURES

In 1998, the government of Palau produced national rules and regulations for a set of species targeted by fishing operations (Table 4).

**TABLE 4. SUMMARY OF EXISTING NATIONAL FISHERY REGULATIONS**

**NATIONAL REGULATIONS**

| COMMON NAME | PALAU NAME | MINIMUM SIZE | HARVESTING SEASON | OTHER RESTRICTIONS |
|---|---|---|---|---|
| Groupers | Tiau, Katuu'tiau, Mokas, Ksau'temekai, Metuengerel'temekai | 12 inches | Closed April 1- October 31 for spawning | |
| Rabbitfish | Meyas | No | Closed February 1- March 31 for spawning | |
| Bumphead Parrotfish | Kemedukl | | Closed year round | No Export |
| Napoleon Wrasse | Maml | | Closed year round | No Export |
| Aquarium Species | | No | Open | Fishing and export restricted to people in possession of an Aquarium Collecting Permit |
| Rock Lobsters | Cheraprukl, Raiklius, Bleyached, Mellech | 6 inches total carapace length | Open | No export; No taking of egg-bearing females whatever the length |
| Mangrove Crab | Emang | 6 inches greatest distance across width of carapace | Open | No export; No taking of egg-bearing females whatever the length |
| Coconut Crab | Ketat | 4 inches greatest distance across width of carapace | Open | No export; No taking of egg-bearing females whatever the length |
| Green Turtle | Melob | 34 inches carapace length | Closed May-August and December-January | No taking of eggs; No taking of female while she is onshore |
| Hawksbill Turtle | Ngasech | Closed | Closed until April 2021 | No taking of eggs; No taking of female while she is onshore |
| Giant Clams | Otkang, Ribkungel, Kism, Melibes, Oruer, Duadeb | No | Open | No export (except cultured specimens) |
| Trochus | Semum | 3 inches basal diameter | Designated from year to year by OEK | State governments can designate closed areas during open seasons |
| Blacklip Pearl Oyster | Chesiuch | 4 inches diameter across the shell | Closed August 1- December 31 | |
| Sea Cucumbers | Bakelungal chedelkelek, Bakelungal cherou, Temetamel, Badelchelid, Molech, Erumrum | No | Open | No export |
| Dugongs | Mesekiu | No | Closed | |
| Sponges, Hard Corals and Marine Rock | | No | Open | No export |

### 3.2.2 PROPOSED NON-SPATIAL MANAGEMENT MEASURES:

Since populations of focal fisheries species are continuing to decline, new non-spatial management measures are proposed for the Northern Reefs, including minimum size limits, species moratoria, seasonal closures, and sex specific regulations (Table 5).

**TABLE 5. PROPOSED NON-SPATIAL MANAGEMENT MEASURES FOR FOCAL FISHERIES SPECIES.**
The projected benefits of the measures, indicators, and review / adjustment process are also outlined.

**NON-SPATIAL MANAGEMENT MEASURES FOR THE NORTHERN REEFS**

| SPECIES NAME | MANAGEMENT MEASURE | NATIONAL REGULATION | TYPE/ DEFINITION | PROJECTED BENEFITS | MEASURABLE INDICATORS | REVIEW/ ADJUSTMENT |
|---|---|---|---|---|---|---|
| Grouper (*Plectropomus leopardus, P. laevis, P. areolatus, Epinephelus polyphekadion, E. fuscogutattus*) | Existing ban on 5 spp. of grouper | | 3-year ban on fishing (July 2015-July 2018) | • Rebuild stocks more quickly<br>• Restore ecosystem and fishery benefits | SCUBA surveys measuring density and abundance of grouper spp. | Reevaluation of closure after 3 years |
| Baselokil (*Variola louti*) | Existing closure in Kayangel | | 3-year spp. specific ban (July 2015-July 2018) | • Rebuild stocks more quickly<br>• Restore ecosystem and fishery benefits | SCUBA surveys measuring density and abundance of Baselokil | Reevaluation of closure after 3 years |
| Baselokil (*Variola louti*) | Proposed Minimum Size limit in Ngarchelong (see Table 6) | | | • Sustained minimum spawning potential to meet target fishery objectives and ecosystem benefits | SPR indicator relative to target level of 20% | Size limits to be implemented immediately |
| Eropk (*Caranx ignobilis*) | Proposed Eropk closure for 3 years | | 3-year spp. specific ban (upon approval of regulation) | • Rebuild stocks more quickly<br>• Restore ecosystem and fishery benefits | fishery dependent size and landings data | Reevaluation of closure after 3 years |
| Mangrove crab (*Scylla serrata*) | Proposed ban on all females harvested at designated areas (e.g. Matul) | Existing National Law on ban of berried females | Permanent ban on all females | • Possible improved reproductive potential<br>• Reduction of fishing pressure | Fishery independent surveys measuring abundance levels | 3years closure for Kayangel State/ 1 year for Ngarchelong State |
| Otkang (*Tridacna gigas*) Kism (*Tridacna derasa*) | Proposed ban on fishing for Otkang and Kism | | Ban (upon approval of regulation) on harvesting for 10 years except for farmed stock and with limited exceptions as defined in the regulation | • Rebuild stocks more quickly<br>• Restore ecosystem and fishery benefits | SCUBA surveys measuring density and abundance of Otkang and Kism spp. | Reevaluation of closure after 10 years |
| Ngesngis ♂ (*Cetoscarus ocellatus*)<br><br>Beyadel ♀ (*Cetoscarus ocellatus*) | Proposed Ngesngis and Beyadel seasonal closure | | Seasonal closure (Mar-April) | Spawning aggregations are believed to peak during this time frame | SPR indicator relative to target level of 20% | Size limits will be put into place as a near-term priority. If the target SPR of 20% is not met within a 5 year period, the seasonal closure will be considered for implementation. |
| Grouper (*Plectropomus leopardus, P. laevis, P. areolatus, Epinephelus polyphekadion, E. fuscogutattus*) | Proposed Minimum Size Limits (see Table 6) | | | Sustained minimum spawning potential to meet target fishery objectives and ecosystem benefits | SPR indicator relative to target level of 20% | Size limits to be implemented when species harvest ban is lifted in 3 years. |
| Nine species of snappers, emperors, unicornfishes, and parrotfishe (see Table5) | Proposed Minimum Size Limits (see Table 6) | | (Table 6) | Sustained minimum spawning potential to meet target fishery objectives and ecosystem benefits | SPR indicator relative to target level of 20% | Size limits to be implemented immediately |

## SIZE LIMITS: IMPLEMENTATION OF MINIMUM SIZE LIMITS FOR 15 SPECIES OF FINFISH

From 2014-2016, research was conducted to determine the size at reproductive maturity for 15 species of finfish in the Northern Reefs region including fishing grounds in the States of Ngarchelong and Kayangel (Prince et al. 2015, Prince

2016). Estimates of size of maturity were coupled with measurements of individual lengths of fish in the catch collected collaboratively with fishermen. Results of the data collection and analysis revealed a large fraction of the catch being harvested prior to reaching reproductive maturity (Prince et al. 2015, Prince unpublished data). Size limits are an extremely important tool for maintaining a minimum level of spawning potential in the stock.

The minimum size limits proposed for these species in this management plan are provided in Table 6. The proposed minimum sizes depicted here ensure these species will have the potential to spawn at least once before being vulnerable to harvest and are set above the size at $L_{50}$. All minimum size limits were decided upon through expert consultation and a consensus-based process using the best available science during the Northern Reef stakeholder working group meetings of early 2016.

Table 6 is separated into two phases of implementation. The species in the top portion of the table require immediate implementation of the size limit. The species in the bottom portion of the table are groupers and will have size limits implemented after the 3-year grouper ban.

TABLE 6. PROPOSED SIZE LIMITS FOR FOCAL FISHERY SPECIES. Detailed overview of 15 finfish species, their Palau name, size at maturity (l50), spawning potential ratio (spr), proposed minimum size limit and time frame of implementation of size limits.

PROPOSED MINIMUM SIZE LIMIT TABLE

| SPECIES | PALAU NAME | LENGTH AT 50% MATURITY (L50) IN MM | CURRENT ESTIMATE OF SPAWNING POTENTIAL RATIO (SPR) | PROPOSED MINIMUM SIZE LIMIT (INCHES) | PROPOSED IMPLEMENTATION |
|---|---|---|---|---|---|
| *Lutjanus bohar* | Kedesau | 434 | 0.27 | *18* | Immediately |
| *Lethrinus olivaceus* | Melangmud | 405 | 0.10 | *18* | Immediately |
| *Naso unicornis* | Chum | 316 | N/A | *16* | Immediately |
| *Lethrinus xanthochilus* | Mechur | 326 | 0.13 | *13* | Immediately |
| *Cetoscarus oscellatus* | Beyadel | 319 | N/A | *13* | Immediately |
| *Chlorurus microrhinos* | Otord | 309 | 0.21 | *13* | Immediately |
| *Hipposcarus longiceps* | Ngyaoch | 300 | 0.05 | *12* | Immediately |
| *Scarus rubroviolaceus* | Rekruk | 290 | 0.07 | *13* | Immediately |
| *Lutjanus gibbus* | Keremlal | 223 | 0.10 | *12* | Immediately |
| *Variola louti* | Baselokil | 203 | 0.20 | *13* | Immediately for Ngarchelong. Implementation to occur after 3 years species closure for Kayangel |
| | | | | | |
| *Plectropomus leopardus* | Red Tiau | 286 | *0.01* | *13* | Implementation to occur after 3 year species closure |
| *Plectropomus areolatus* | Black Tiau | 365 | 0.05 | *16* | Implementation to occur after 3 year species closure |
| *Plectropomus laevis* | Mokas | N/A | N/A | 24 | Implementation to occur after 3 year species closure |
| *Epinephelus fuscogutattus* | Meteungerel'temekai | N/A | N/A | 16 | Implementation to occur after 3 year species closure |
| *Epinephelus polyphekadion* | Ksau'temekai | N/A | N/A | 16 | Implementation to occur after 3 year species closure |
| *Bolbometapon muricatum* | Kemedukl | 680 | | | |

## SPECIES BANS: MORATORIUMS ON FISHING FOR SPECIFIED TIME PERIODS: FINFISH AND INVERTEBRATE SPECIES

*Grouper*: Existing three-year moratorium on fishing.
In July 2015, the States of Ngarchelong and Kayangel implemented a three-year moratorium on fishing for all species of grouper including Red Tiau (*Plectropomus leopardus*), Black Tiau (*Plectropomus areolatus*), Mokas (*Plectropomus laevis*), Meteungerel'temekai (*Epinephelus fuscoguttatus*), and Ksau'temekai (*Epinephelus polyphekadion*). The three-year ban is intended to rebuild the stocks to levels that will allow greater yields to be harvested in a managed fishery. Coupled with size limits pending the opening of the fishery (Table 5), it is expected that the fishery will operate at spawning potential levels greater than $SPR_{20}$.

*Baselokil (Variola louti):* Three-year moratorium on fishing in Kayangel State and a proposed size limit in Ngarchelong State. A three-year moratorium on fishing of Baselokil currently exists in the State of Kayangel. Similar to the species ban for groupers, this regulation is intended to rebuild the stocks to operate at spawning potential levels greater than $SPR_{20}$. In addition to this ban in Kayangel, a proposed size limit of 13 inches is placed for fishing for Baselokil in the State of Ngarchelong and will contribute to the broader goals of maintaining healthy ecosystems and rebuilding the entire fishery to levels consistent with management objectives.

*Eropk (Caranx ignobilis):* Three-year moratorium on fishing.
The proposed three-year moratorium on Eropk is intended to rebuild depleted stocks and provide increased fishing opportunities in the future. Giant trevally is fished for subsistence, commercial, and sport. Very little data is available for this species in the Northern Reefs, but anecdotal evidence suggests declining stocks. Catch-and-release fishing will be allowed in specific zones (e.g. Ngkesol) during the closure (see Spatial Management 3.3; Table 6). No take of this species is allowed during the three-year moratorium. To evaluate the success of the fishing closure, monitoring should be conducted to evaluate fishery's dependent and independent data.

*Otkang (Tridacna gigas) and Kism (Tridacna derasa):* Ten-year moratorium on fishing
All species of giant clam are currently regulated in the national law. Regulations specify that no clam shall be harvested for export purposes. There is no minimum size limit or seasonal closure at the national level. In the States of Ngarchelong and Kayangel a ten-year moratorium on fishing for two main species of giant clam (Kism and Otkang) will serve to rebuild depleted stocks and contribute to healthy ecosystems and enhanced fishing opportunities. No harvest of wild stocks will be allowed during the ten-year moratorium. All farmed (aquaculture) stocks of Otkang and Kism will be open to harvest and sale.

*Lobster (Panulirus genus):* Three-year moratorium on fishing
National law specifies a permanent ban on the take of egg-bearing females throughout Palau including size limits. The three-year ban on the take of lobsters is intended to increase spawning and reproduction and to rebuild the fishery to operate at spawning potential levels greater than $SPR_{20}$. Evaluation of the ban will take place after a three-year time period at which time fishery's dependent and independent data will be reviewed.

*Aquarium trade species:* Moratorium on fishing
Aquarium trade species are those reef fish and invertebrates that are harvested specifically for display in personal, public and commercial aquaria. No take of aquarium trade species will be allowed except on a case-by-case basis. Such case specific considerations may include domestic public aquaria collectors (e.g. PICRC) and species specific export considerations. Permits and approval must be granted prior to any take of aquarium trade species. Collecting for scientific research will be considered on a case-by-case basis and is covered in the permitting section.

## SEX-SPECIFIC REGULATIONS FOR MANGROVE CRAB

*Mangrove Crab (Scylla serrata):* Three-year moratorium on fishing for Kayangel and one-year moratorium on fishing for Ngarchelong State. National law specifies a permanent ban on the take of egg-bearing females throughout Palau. The three-year ban for Kayangel and one-year on the take of all female crabs is intended to increase spawning and reproduction and to rebuild the fishery to operate at spawning potential levels greater than $SPR_{20}$. Evaluation of the ban will take place after a three-year and one-year time period at which time fishery dependent and independent data will be reviewed.

## 3.3 SPATIAL MANAGEMENT MEASURES

Spatial management measures are also recommended to protect important ecosystems that support all species, rebuild fish populations, protect spawning areas and other sensitive sites, and zone or limit activities that have adverse impacts on the ecosystem and fishery resources. Spatial management measures, such as zoning of activities can help to manage and protect the values of the Northern Reefs that are important to the local people and to Palau. Different types of spatial management zones will have different benefits for fisheries and ecosystem protection goals, depending on the level of protection they afford to marine habitats and species. For example, fully-protected no-take zones can promote rebuilding of populations of important fishery resources (Lester et al. 2009; McClanahan et al. 2007; Halpern et al. 2010; Harrison et al. 2012). Similarly, spatial management zones will differentially affect fishermen and other community members depending on what resource-use activities are disallowed or limited.

In a comprehensive zoning scheme, each zone has different rules for the activities that are allowed, the activities that are prohibited, and the activities that require a permit. Zones may also place restrictions on how some activities are conducted. Some key types of spatial management zones include:

- *Fully-protected no-take zones (NTZ)*: zones that prohibit all extractive and destructive activities that provide the most protection to a broad range of habitats and species. If designed properly and effectively managed, no-take zones provide the most benefits toward rebuilding fish populations and protecting ecosystems and a broad range of species.
- *Limited-take zones:* zones that protect some species, but allow other species to be taken (e.g. a mangrove crab closure area that only protects that species of crab, while allowing other species to be harvested), can support rebuilding of some species, while reducing socioeconomic impacts on resource users. The level of ecosystem protection afforded by limited-take zones depends on how many species, and what types of species, are allowed to be harvested.
- *Limited-use or Multiple-use zones:* zones that allow for or limit certain activities, including fishing or tourism activities, can help to focus impacts on certain areas, while protecting other areas from those activities. These types of activity zones should be managed for long-term sustainable use.

Spatial management measures can be designed to achieve multiple objectives, including protecting ecosystems and habitats, and promoting the rebuilding of important fish populations in the face of human activities, climate change, and other threats (Green et al. 2014a). There are a variety of design principles and guidelines that can help ensure protected areas are located in the right habitats and are of sufficient size and spacing to support their intended goals (Green et al. 2014a; Green et al. 2014b; Saarman et al. 2013). Generally, to best support rebuilding of fish populations and reef health, fully-protected no-take zones are recommended. These no-take zones should represent and replicate key habitats, be large enough to sustain populations of focal species, and be spaced close enough together to support connectivity of fish populations through larval transport (Green et al. 2014b). It is also important to protect a portion of all of the habitats needed by various life stages of focal fishery species, including key nursery habitats and spawning sites (Green et al. 2014a). The benefits of no-take zones, in terms of rebuilding focal fish populations, can take many years to accrue depending on many factors including the life history and vulnerability of focal species and the level of fishing pressure outside the MPAs (Abesamis et al. 2014).

A comprehensive zoning scheme for the Northern Reefs is anticipated to provide the following types of benefits (after Kelleher 1999):

- provide protection for critical and representative habitats, ecosystems, and ecological processes and to promote rebuilding of focal fish populations;
- separate conflicting human activities (e.g. subsistence and commercial harvest);
- protect core zones with fully-protected no-take status, while allowing a spectrum of reasonable human uses in other zones; and
- reserve suitable areas for particular human uses (e.g. tourism activities), while minimizing the effects of those uses on the other parts of the area.

This effort to design spatial management measures builds upon previous work to identify and implement a PAN design, as well as existing management plans that have been in place in Kayangel and Ngarchelong for some time (Ngarchelong Marine Resource Planning Team, 2011; Ngedebuul Conservation and Resource Planning Team, 2012). In the Northern Reefs, fishermen have seen some benefits of rebuilding fish populations within Ebiil Channel Conservation Area and Ngaruangel Nature Reserve, which are both well designed and managed no-take areas. Recent stereo-video surveys of fish abundance and size at 190 sites in the Northern Reefs have shown larger sizes of many, though not all, species of fishes inside the Ebiil and Ngaruangel no-take areas compared to fished areas nearby (Lindfield et al. 2015).

While these fully-protected no-take areas have helped to rebuild stocks of some species within their borders, the perception is that they have proven to be insufficient to reverse the decline in fishery resources in the Northern Reefs. That is not surprising since these areas alone do not fulfill the design criteria required to achieve fisheries management objectives (e.g. the need to protect 20-30% of each habitat type in no-take areas, protect critical habitats, and make sure that no-take areas are large enough to protect focal fisheries species: see Green et al. 2014a). Furthermore, for no-take areas to be effective fisheries management tools, they must be integrated with other fisheries management measures (e.g. to protect wide-ranging species that may move outside the no-take areas).

Thus a more comprehensive spatial management scheme, with additional fully-protected no-take zones and limited-use zones (e.g. for subsistence fishing) and an effective enforcement program, are now seen as critical to achieve both fisheries improvement and ecosystem protection goals. There is also a strong interest by the communities to limit certain types of activities (e.g. commercial fishing) to specific zones to reduce the impacts of those activities broadly across the Northern Reefs.

The Ngarchelong-Kayangel Planning Team met frequently over a 3-month period and used available data and local knowledge of local resource users to identify potential spatial management measures that would help to achieve the overall goals of improving fisheries, protecting ecosystems, and retaining local access and benefits in the Northern Reefs. Since these spatial management measures alone are likely to be insufficient to meet fishery management goals, they are being implemented in parallel with non-spatial harvest control rules for key fishery species and a permitting scheme to restrict and track access (see Sections 3.1 and 3.2).

## COMPREHENSIVE SPATIAL MANAGEMENT ZONING SCHEME

The Planning Team used local knowledge, habitat mapping, and data on fish biomass and size structure to identify spatial management areas to better protect important ecosystems, rebuild fish stocks, and zone activities. The existing protected areas and zones were reviewed and incorporated, with the addition of new zones, into a comprehensive spatial zoning scheme for the entire Northern Reefs area (Table 7, Figure 9). The existing and proposed new marine management zones include:

- *Zone 1: Ngeruangel Nature Reserve (existing zone):* This area has been protected since 1996 with strictly regulated harvest that needs approval from Governor and traditional Chiefs Kayangel State for a sanctioned event. Ngeruangel Nature Reserve is 16.4 sq. mi. (42.5 sq. km.) in size and protects a significant proportion of bank, shelf, and fore reef habitat.
- *Zone2: Kayangel Subsistence Fishing Zones (existing zone):* This zone around Kayangel reef have been zoned for subsistence fishing;
- *Zone3: Kayangel and Ngarchelong Subsistence Fishing Zone:* There are two zones, one around Kayangel reef and the other on the eastern half of Ngkesol reef that have been zoned for subsistence fishing; these two areas total 50 sq. mi. (129.5 sq. km.). While some type of MPA was previously discussed for Ngkesol reef and was identified in the Conservation Act as a potential area for a rotational closure (with additional protection for spawning aggregation sites for a few days around the new and full moon), it was never fully implemented due to lack of capacity. A fully-protected no-take zone around part of Ngkesol reef has now been incorporated into the new proposed spatial management scheme (see Zone 5).
- *Zone 4: Velasco Commercial Fishing Zone (proposed zone):* This area, encompassing 99.5 sq. mi. (255.4 sq. km.) of Velasco Reef within the 12 nmi state boundary, is the only area in Kayangel zoned for non-resident commercial fishing, with the intention of focusing that activity in that area. Resident commercial and

subsistence fishing is also allowed in this zone. All of these fishing activities require a permit, and Resident and Non-resident Commercial Permits are each limited in number to three. The permitting measures, and the far distance of this reef from population centers, will help to limit fishing in this area.

- *Zone 5: Ngkesol-Ngerael No–take Zone (proposed zone):* This area, a total of 43.6 sq. mi. (112.9 sq. km.), encompasses a large area of reef including all of Ngerael Reef in Ngarchelong State and some of Ngkesol Reef in Kayangel State, as well as the pass, known to be a spawning site, in between the two reefs. This large zone is a no-take zone, except for allowing catch-and-release fishing with a Recreational Fishing Permit. The intention of this zone is to fully protect the inner and outer reef, reef pass, and associated reef species, while allowing for and promoting catch-and-release sport fishing as a revenue generating activity.
- *Zone 6: Ebiil Channel Conservation Area (existing zone):* The channel area has been zoned as a permanent, fully-protected no-take zone since 2000 for protection of spawning aggregations with the area of protection expanded in 2003. This no-take zone is 6.7 sq. mi. (17.4 sq. km.) in size, representing about 3% of the main lagoon area, and protects much of the channel habitat in the lagoon.
- *Zone 7: Matul Crab Closure Zone (proposed zone):* This small area (0.26 sq. mi. or 0.67 sq. km.) on the western side of Ngarchelong is zoned as a closure area for mangrove crab after one year moratorium, with the intention of reducing fishing pressure on mangrove crabs to promote rebuilding of that fishery. Other subsistence fishing activities are allowed, with a permit.
- *Zone 8: Ngarchelong Subistence Zone (proposed zone):* The remaining large reef and lagoon complex in Ngarchelong (total area of 171.6 sq. mi. or 444.4 sq. km.) is zoned for subsistence fishing, with the required permit. No commercial fishing is allowed inside the reef in Ngarchelong.
- *Zone 9: Commercial Fishing Zone (proposed zone):* Resident commercial and subsistence fishing is also allowed in this zone. All of these fishing activities require a permit, and Resident and Non-resident Commercial Permits are each limited in number to three. The permitting measures, and the far distance of this reef from population centers, will help to limit fishing in this area.

## IMPLEMENTATION OF THE ZONING SCHEME

A comprehensive zoning scheme ensures that all parts of the Northern Reefs complex are under management with clear intentions about the types of activities that are allowed or disallowed in each zone. This comprehensive zoning approach will only work if there is community acceptance and mechanisms to enforce the underlying regulations in each zone. The feasibility of implementing and enforcing the comprehensive spatial zoning scheme will be greatly facilitated by:

- permitting process that allows for tracking of activities and fish catch;
- boat licensing and use of flags to identify activities boats are engaged in while on the reef;
- development and distribution of zoning maps with clear regulations;
- public awareness campaign to ensure that residents, non-residents, and tourist operators understand and comply with the zoning scheme; and
- effective compliance and enforcement program.

To support the implementation of the zoning scheme, outreach materials that clearly show the spatial management zones and articulate allowed activities should be developed and distributed to the communities, tour operators, and Koror-based fishermen**.**

## FIGURE 9. COMPREHENSIVE SPATIAL ZONING SCHEME FOR PALAU'S NORTHERN REEFS

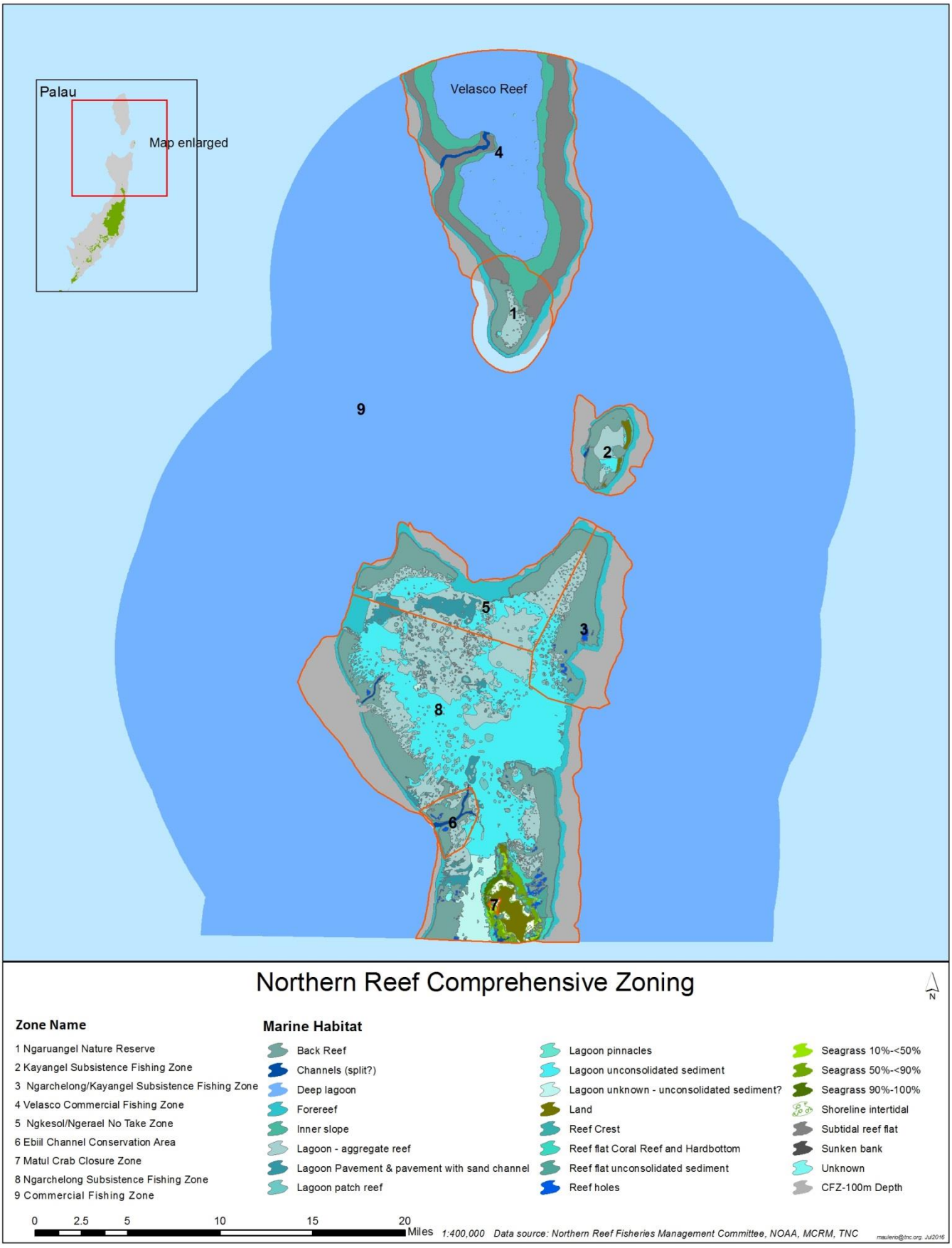


**TABLE 7. EXISTING AND PROPOSED SPATIAL MANAGEMENT MEASURES IN A COMPREHENSIVE MARINE ZONING SCHEME** These categories are based on the ecology of each species (Table 10) and the characteristics of each zone including: the relative protection afforded by each type of zone and the habitat types located within the zone; and how much of each habitat type is included in each zone**.** Where: dark green=fully-protected no-take zone; light green=no-take zone with catch-and-release sport fishing; dark blue=subsistence fishing zone; light blue=commercial fishing zone; and orange=crab closure zone.

| ZONE # | MANAGEMENT ZONE | TYPE OF ZONE | PROJECTED BENEFITS TO ECOSYSTEMS & PEOPLE | MEASURABLE INDICATORS | REVIEW/ ADJUSTMENT PROCESS |
|---|---|---|---|---|---|
| 1 | Ngeruangel Nature Reserve (existing) | Permanent no-take zone; no access except for permitted customary use | • Ecosystem benefits to a broad range of reef and lagoon habitats, and species dependent on those habitats<br>• Rebuild fisheries by protecting a full range of species, habitats, and spawning areas | Live coral cover and resilience and fish size and abundance trends over time inside / outside no-take zone | Review after 3 years to evaluate effectiveness |
| 2 | Kayangel Subsistence Fishing Zone (existing) | Zoned for subsistence fishing | • Secures local access to fishery resources near villages and removes commercial fishing pressure<br>• Ecosystem benefits to a broad range of reef and lagoon habitats and species dependent on those habitats | Size and abundance of fish in subsistence catch and on reef over time | Review after 3 years to evaluate effectiveness |
| 3 | Kayangel and Ngarchelong Subsistence Fishing Zone (existing) | Zoned for subsistence fishing | • Secures local access to fishery resources near villages and removes commercial fishing pressure<br>• Ecosystem benefits to a broad range of reef and lagoon habitats and species dependent on those habitats | Size and abundance of fish in subsistence catch and on reef over time | Review after 3 years to evaluate effectiveness |
| 4 | Velasco Commercial Fishing Zone (proposed) | Zoned for non-resident commercial fishing | • Reduced commercial fishing pressure in Ngkesol and other areas as commercial pressure limited to 3 permitted boats in Velasco reef only<br>• Multiple use area with lots of activities permitted but far distance from human populations will limit impacts | Size and abundance of subsistence and commercial catch and on reef over time | Review after 3 years to evaluate effectiveness |
| 5 | Ngerael-Ngkesol No-take Zone (proposed) | No-take zone, except for catch-and-release sport-fishing only (w/ permit) | • Ecosystem benefits to a broad range of reef and lagoon habitats and many species dependent on those habitats<br>• Rebuild fisheries by protecting a wide range of species, habitats, and fish spawning areas<br>• Some mortality expected from catch-and-release<br>• Revenue generated from tourism permit fees | • Live coral cover and resilience and fish size and abundance trends over time inside / outside no-take zone<br>• Size and abundance of "trophy" catch-and-release target species<br>• Revenues generated from tourism activities | Review after 3 years to evaluate effectiveness |
| 6 | Ebiil Channel Conservation Area (existing) | Permanent no-take zone | • Ecosystem benefits to a broad range of reef and lagoon habitats and species dependent on those habitats<br>• Rebuild fisheries by protecting a wide range of species, habitats, and spawning areas | Live coral cover and resilience and fish size and abundance trends over time inside / outside no-take zone | Review after 3 years to evaluate effectiveness and consider expansion of area if necessary |
| 7 | Matul Crab Closure Zone (proposed) | No take of mangrove crab | Reduce pressure on mangrove crabs to promote rebuilding of fishery | Size and abundance of mangrove crabs inside/outside closure over time | Review after 1year to evaluate effectiveness |
| 8 | Ngarchelong Subsistence Fishing Zone (proposed) | Zoned for subsistence fishing only | • Maintain local access to fishery resources near villages<br>• Rebuild or halt decline of fish populations faster by reducing commercial fishing pressure inside the reef complex<br>• Protect full range of habitats and species | Size and abundance of fish in subsistence catch and on reef over time. | Review after 3 years to evaluate effectiveness |

| | | | | | |
|---|---|---|---|---|---|
| 9 | Commercial Fishing Zone | Zoned for Commercial Fishing | • Reduced commercial fishing pressure in Ngkesol and other areas as commercial pressure limited to 3 permitted boats. Multiple use area with lots of activities permitted but far distance from human populations will limit impacts | Size and abundance of subsistence and commercial catch and on reef over time | Review after 3 years to evaluate effectiveness |

## 3.4 INTEGRATION OF SPATIAL FISHERIES MANAGEMENT INTO PAN DESIGN

This Fisheries Management Plan for the Northern Reefs includes a comprehensive zoning scheme that is focused on both ecosystem protection and fisheries improvement goals, and also incorporates additional fishery management measures such as permitting and harvest control rules. This approach, of integrating non-spatial and spatial management measures, is designed to achieve the fishing improvement goals identified by the Fisheries Management Planning Team, as well as contribute to the overall PAN goals for ecosystem and biodiversity protection in the region.

The comprehensive zoning scheme for the Northern Reefs includes a significant area (68.8 sq. mi.) in four no-take zones, and thus should contribute significantly to support PAN ecosystem protection objectives for these two states.

**TABLE 8. ALLOWED ACTIVITIES AND PROTECTION STATUS OF SPATIAL MANAGEMENT ZONES**

| ZONE | AREA (SQ. MI.) | ALLOWED ACTIVITIES | PROTECTION LEVEL | NOTES |
|---|---|---|---|---|
| 1. Ngaruangel Nature Reserve | 16.4 | No-take zone, with no access. Limited use with approval from Kayangel Governor and Chiefs as outlined in Ngaruangel Management Plan | High | Assumes customary use is limited and sustainable |
| 2. Kayangel Subsistence Fishing Zone | 50 | Subsistence fishing only (w/permit) | Moderate | Assumes subsistence and *makit* fishing is limited and sustainable |
| 3. Kayangel and Ngarchelong Subsistence Fishing Zone | 50 | Subsistence fishing only (w/permit) | Moderate | Assumes subsistence and *makit* fishing is limited and sustainable |
| 4. Velasco Commercial Fishing Zone | 98.6 | Only permitted commercial fishing (w/permit); subsistence fishing allowed (w/permit); recreational fishing (w/permit) | Low | Assumes combination of commercial and subsistence fishing offers limited protection; however, distance and number of fishermen may limit impacts |
| 5. Ngkesol / Ngeraelel No-Take Zone | 43.6 | No-take zone, except for catch-and-release sport-fishing only (w/permit) | High | Assumes no fishing mortality |
| 6. Ebiil Channel Conservation Area | 6.7 | Permanent no-take zone | High | Assumes no fishing |
| 7. Matul Crab Closure | 0.3 | No-take of mangrove crab is allowed; other subsistence fishing is allowed (w/permit) | Low | Only protects mangrove crab |
| 8. Ngarchelong Subsistence Fishing Activity | 171.6 | Subsistence fishing only (w/permit); commercial fishing w/permit is only allowed outside of the reef | Moderate | Assumes subsistence and *makit* fishing is limited and sustainable |
| 9. Commercial Fishing Zone | | Only permitted commercial fishing (w/permit); subsistence fishing allowed (w/permit); recreational fishing (w/permit) | Low | Assumes combination of commercial and subsistence fishing offers limited protection; however, distance and number of fishermen may limit impacts |

A preliminary gap assessment of the habitats (as per Victor et al. 2015) protected in each management zone (Table 9, Figure 10) shows that for many habitats (fore-reef, reef crest, back reef, lagoon reef and pavement, channels, and seagrass) a significant portion (>20% as per PAN guidelines) of each available habitat in this region is protected in high protection no-take zones. Since reef habitats and communities differ with exposure to ocean waves and currents, it should be noted that there is less protection afforded to the reef habitats on the eastern side of the reef complex (see stratification units in Victor et al. 2015).

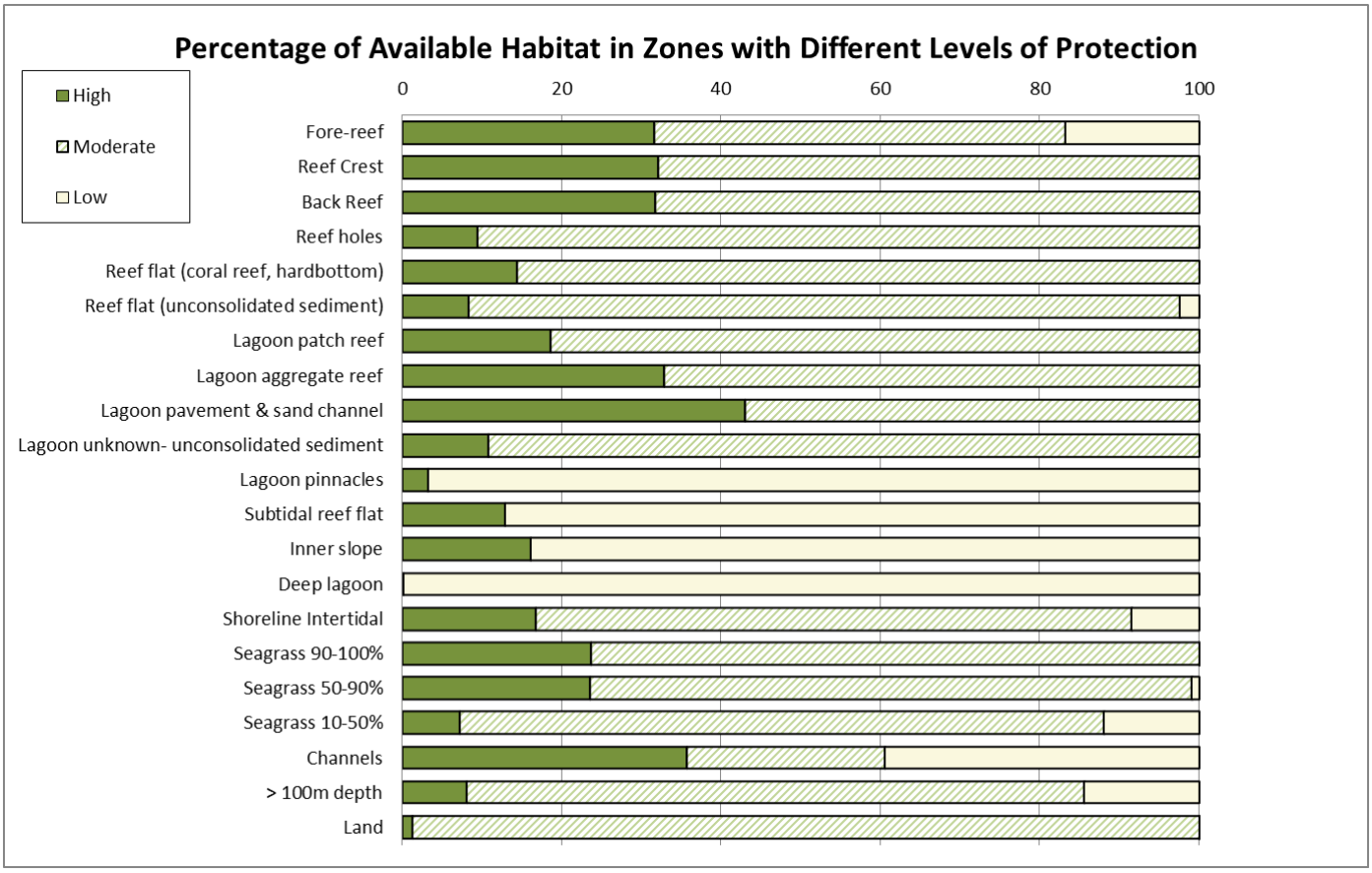
A large proportion of other habitat types are in protection zones that allow some fishing pressure. If subsistence and *makit* fishing pressure is limited, these habitats and associated species will likely benefit from these protection zones. A significant portion of seagrass nursery grounds and spawning sites in channels are also protected.

**TABLE 9. AMOUNT OF EACH HABITAT TYPE BY ZONE IN THE NORTHERN REEFS**

| | Ngaruangel Nature Reserve | Kayangel Subsistence Fishing Zone "A" | Kayangel and Ngarchelong Subsistence Fishing Zone "B" | Velasco Commercial Fishing Zone | Ngkesol/Ngerael No-Take Zone | Ebiil Channel Conservation Area | Matul Crab Closure | Ngarchelong Subsistence Fishing Zone | Ngarchelong& Kayangel Subsistence Fisihing Zone | Total Habitat Available |
|---|---|---|---|---|---|---|---|---|---|---|
| **ZONE #** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | |
| **PROTECTION LEVEL** | **HIGH** | **MODERATE** | **MODERATE** | **LOW** | **HIGH** | **HIGH** | **LOW** | **MODERATE** | **LOW** | |
| **HABITATS** | | | | | | | | | | |
| Fore reef | 2.41 | 2.19 | 3.48 | 4.49 | 5.77 | 0.29 | 0.00 | 8.15 | | **26.79** |
| Reef crest | 0.23 | 0.30 | 0.27 | 0.00 | 0.54 | 0.14 | 0.00 | 1.37 | | **2.86** |
| Back reef | 3.58 | 3.96 | 9.51 | 0.00 | 9.84 | 2.73 | 0.00 | 21.66 | | **51.42** |
| Reef holes | 0.00 | 0.00 | 0.46 | 0.00 | 0.00 | 0.15 | 0.00 | 1.17 | | **1.81** |
| Reef flat (coral reef, hard bottom) | 0.00 | 0.25 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 2.25 | | **2.92** |
| Reef flat (unconsolidated sediment) | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 1.38 | | **1.55** |
| Lagoon patch reef | 0.07 | <0.01 | 0.88 | 0.00 | 1.02 | 0.29 | 0.00 | 5.42 | | **7.74** |
| Lagoon aggregate reef | 2.17 | 2.21 | 2.57 | 0.00 | 13.19 | 1.88 | 0.00 | 30.98 | | **53.25** |
| Lagoon pavement & sand channel | 0.00 | 0.00 | 0.01 | 0.00 | 3.25 | 0.02 | 0.00 | 4.33 | | **7.62** |
| Lagoon unknown-unconsolidated sediment | 0.05 | 0.70 | 4.46 | 0.00 | 6.75 | 0.63 | 0.00 | 57.55 | | **70.30** |
| Lagoon pinnacles | <0.01 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | | **0.12** |
| Subtidal reef flat | 3.20 | 0.00 | 0.00 | 21.73 | 0.00 | 0.00 | 0.00 | 0.00 | | **24.93** |
| Inner slope | 2.79 | 0.00 | 0.00 | 14.55 | 0.00 | 0.00 | 0.00 | 0.00 | | **17.34** |
| Deep lagoon | 0.06 | 0.00 | 0.00 | 48.01 | 0.00 | 0.00 | 0.00 | 0.00 | | **48.06** |
| Shoreline intertidal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.99 | | **1.33** |
| Seagrass 90-100% | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | <0.01 | 0.54 | | **0.84** |
| Seagrass 50-90% | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 1.61 | | **2.13** |
| Seagrass 10-50% | 0.00 | <0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.56 | | **0.70** |
| Channels | 0.00 | 0.09 | 0.00 | 0.67 | <0.01 | 0.60 | 0.00 | 0.34 | | **1.70** |
| > 100m depth | 1.80 | 6.72 | 11.16 | 8.99 | 3.20 | <0.01 | 0.00 | 30.10 | | **61.97** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Land | 0.01 | 0.66 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 3.24 | | **3.96** |
| **TOTAL AREA** | **16.41** | **17.19** | **32.81** | **98.57** | **43.61** | **6.75** | **0.26** | **171.65** | | **389.39** |
| **NOTE: NO DATA AVAILABLE FOR "SUNKEN BANK" OR "MANGROVE" HABITAT TYPES** | | | | | | | | | | |

**FIGURE 10. PERCENTAGE OF AVAILABLE HABITAT BY PROTECTION STATUS** (with high protection zones 1, 4, 5, and 6; moderate protection zones 2a, 2b, and 8; and low protection zones 3 and 7)




## 3.5 PRELIMINARY ASSESSMENT OF POTENTIAL BENEFITS OF SPATIAL MANAGEMENT ZONES FOR FOCAL FISHERY SPECIES

The potential benefits of existing and proposed spatial management zones (Table 7, Figure 9) for focal fisheries species were examined by a two-step preliminary process. First, the ecological characteristics of focal fisheries species and the implications for the design of spatial management measures were reviewed (Table 9): where the most benefits are likely to accrue for focal species (particularly species that are most vulnerable to fishing pressure); and where spatial management areas encompass their full range of key habitats and movement patterns. For some species, this can be accomplished if spatial management areas include appropriate habitats that are more than twice the size of the home range of the focal species (in all directions and including resident spawning areas: Green et al. 2014b). In contrast, wide-ranging species whose movement patterns (e.g. transient spawning migrations or long term movements) may take them outside the spatial management area will only be afforded partial protection. Although spatial management areas can still provide benefits for these wide-ranging species if they protect their core areas of use or specific locations where individuals aggregate and become especially vulnerable to fishing mortality (e.g. fish spawning areas: Green et al. 2014b). However, it is important to acknowledge that if the scale of movement is too large to be encompassed within the spatial management area, then other non-spatial management measures will be crucial to managing these species (e.g. seasonal closures at spawning times, size limits and species bans).

Second, the potential benefits of each of the existing and proposed spatial management measures were examined (Table 11) for each focal fisheries species based on the ecology of each species (Table 10 and expert judgment where no data were available) and the characteristics of each zone. Where the characteristics of each zone included: the

relative protection afforded by each type of zone (Table 7); the habitat types located within the zone (Table 9); and how much of each habitat type is included in each zone (Figure 10).

For this assessment, we assumed that each of the zones will be effectively managed and that:

- benefits will accrue within well-designed (based on the ecology of focal species), fully-protected no-take zones will be high, while few benefits will accrue within fully-protected no-take zones that are not well designed (e.g. if they are in the wrong habitat or if they are too small to protect focal species); and
- some benefits will accrue within subsistence fishing zones and few benefits will accrue in commercial fishing zones. However, it is important to note that the net benefits of the subsistence and commercial fishing zones will depend on the actual levels of fishing in each zone and the relative contribution of the non-spatial fisheries management measures to managing stocks of focal species.

There is likely to be substantial variation among the existing and proposed spatial management measures regarding the potential benefits they are likely to provide for focal fisheries species (Table 7).

### EXISTING ZONES 1. NGARUANGEL NATURE RESERVE AND 6. EBIIL CHANNEL CONSERVATION AREA

These two existing no-take areas are likely to provide substantial benefits to at least four of the 19 focal fisheries species (*Naso unicornis*, *Cetoscarus oscellatus*, *Hipposcarus longicepts*, and *Scarus rubroviolaceus*), because they include the key habitats these species use and are large enough to accommodate their movement patterns (Table 7).

Three other focal fisheries species are also likely to benefit substantially from Ngaruangel Nature Reserve (*Plectropomus leopardus, Variola louti and Chlorurus microrhinos*) for the same reasons, although the benefits for these species are likely to be less in Ebiil Channel Conservation Area, because that no-take area is smaller. For these three species to be protected more effectively in Ebiil Channel Conservation Area, the minimum linear distance of the no-take area would need to be increased to least 3.7 miles.

Most other focal fisheries species are also likely to receive some benefits from these two reserves, particularly the three species of grouper that spawn in Ebiil Channel. However, since most of the other focal fisheries species are wide ranging, they are likely to only be protected some of the time (while they are in the reserve). So other management measures will be required to manage these species in addition to these no-take areas.

Many other fisheries species are likely to benefit substantially from these no-take zones, particularly those that live in the relevant habitats and do not move very far (summarized in Table 1, Green et al. 2014b) including:

- food fishes such as goatfishes and many smaller species of surgeonfish and unicorn fish (e.g. *Naso vlamingii, Ctenochaetus striatus, Acanthurus lineatus, Zebrasoma scopas*), groupers (e.g. all *Cephalopholis* species and small *Epinephelu*s species), snappers (e.g. *Lutjanus carponotatus* and L. fulviflamma), and parrotfishes (e.g. Chlorurus sordidus); and
- aquarium fishes such as butterflyfishes, angelfishes, and damselfishes.

### PROPOSED ZONE 5. NGKESOL/NGERAEL NO-TAKE ZONE (WITH CATCH-AND-RELEASE SPORT FISHING FOR GIANT TREVALLY CARANX IGNOBILIS)

This is an excellent choice and design for a new fully-protected no-take zone because it encompasses a large area that includes a variety of habitat types, so it is likely to provide substantial benefits for many of the focal fisheries species.

A recent analysis regarding Mapping Ocean Wealth from coral reef fisheries in Micronesia (Harborne 2016) also showed this area is a great choice for a new no-take zone, because it is far from human populations (so fishing pressure is moderate to low on a regional scale), and the standing stock is relatively high, particularly on the northwestern corner, which is more sheltered and thus may have a higher coral cover (and therefore a higher fish biomass) than the northeastern side. Harborne's analysis also predicts that the biomass of key fisheries species could

potentially increase by ~30-60% (potentially higher for herbivores) if this area were protected within a no-take zone, which is likely to provide substantial benefits in terms of spillover and larval transport to nearby fished areas.

This proposed no-take area also includes a variety of habitat types including a pass (and proximity to a pass is predicted to increase standing stock Harborne 2016), so it is likely to provide benefits for a wide range of coral reef species. It is also particularly good that the proposed area spans a range of biophysical gradients that may have different influences on different species (see Harborne 2016). For example, it includes habitats on both the northwestern and northeastern sides (to capture the benefits of both more exposed and sheltered habitats). For example, herbivores are predicted to be more abundant on the more sheltered (northwestern) side compared to the more exposed (northeastern) side where carnivores are predicted to be more abundant (i.e. groupers, *Caranx* and *Lutjanus boh*ar).

Ideally, it would have been better to expand this no-take zone further east to include more habitat types, particularly the entire point on the northeastern side (which is likely to provide important home range and spawning habitats for focal species) and some of the reef on the more exposed eastern side of Ngkesol Reef (both of these areas are currently within Kayangel Subsistence Fishing Zone). If these areas were to be included, they would be likely to include more habitats for more species and improve the habitat representation and replication of exposed eastern reefs that are protected within no-take zones in the PAN.

Given the size of the area and the habitat types that are included, this proposed no-take zone is likely to provide substantial benefits to nine of the 19 focal species whose key habitats and home range (or core area of use) movements are included within this area (Tables 10 and 11). This will include the same seven focal species that are likely to benefit substantially from the Ngarugangel Nature Reserve (see above and Table 11), as well as two other iconic species that are more wide ranging (*Bolbometopon muricatum* and *Cheilinus undulatus*). Many other smaller fisheries species are likely to benefit substantially from these no-take zones, including many food fishes (goatfishes and smaller surgeon fishes, unicorn fishes, groupers, snappers, and parrotfishes) and aquarium fishes (butterflyfishes, angelfishes, and damselfishes).

Most of the other focal fisheries species are also likely to receive some benefits from this proposed no-take zone, although since they are so wide ranging, they are likely to leave the no-take zone so they are only likely to be protected some of the time (while they are in the reserve). So other management measures will also be required to manage these species.

Another consideration is the likely impacts of the proposed catch-and-release sport fishery for *Caranx ignobilis* in this zone. This will depend on several considerations including how this fishery will be managed and the likely survival rates of the fish after capture. One consideration is that this zone is likely to be one of the few no-take zones that will be large enough to protect the core areas of use of this species (Table 10), so perhaps this species warrants a higher level of protection in this zone. However, since this species is wide ranging, individuals that have their core areas of use within the no-take area are also likely to leave the area during longer-term movements where they may be captured in the adjacent subsistence fishing zones.

### EXISTING ZONE 2. KAYANGEL SUBSISTENCE ZONE AND PROPOSED ZONE 3. KAYANGEL AND NGARCHELONG SUBSISTENCE FISHING ZONE AND ZONE 8. NGARCHELONG SUBSISTENCE FISHING ZONE

All three of these subsistence fishing zones are likely to provide some benefits to most of the focal fisheries species, since they include a variety of key habitat types and they are large enough to encompass the homes range (or core area of use) of several species (Tables 10 and 11). This is particularly true for the proposed Kayangel & Ngarchelong Subsistence Fishing Zone that covers a very large area and encompasses one of the greatest varieties of habitat types of all of the zones (Figure 9).

The actual benefits to focal fisheries species will depend on their intrinsic vulnerability to fishing pressure (Table 10), as well as the actual levels of fishing and the relative contribution of the non-spatial fisheries management measures to managing stocks of these species in these zones.

## PROPOSED ZONE 4. VELASCO COMMERCIAL FISHING ZONE AND ZONE 9. COMMERCIAL FISHING ZONE

This zone is likely to provide some benefits to focal fisheries species since it includes a wide range of habitat types, and it is large enough to encompass the home ranges (or core areas of use) of many key species.

Although the actual benefits to focal fisheries species will depend on their intrinsic vulnerability to fishing pressure (Table 10), as well as the actual levels of fishing and the relative contribution of the non-spatial fisheries management measures to managing stocks of these species.

## PROPOSED 7. MATUL CRAB CLOSURE ZONE

This zone is unlikely to provide any benefits for focal fisheries species of finfish, because it is a very small area that seems to include only one habitat type that is not important for most focal species. It is also unclear how likely it is to be effective for the target species (mangrove crab), and the design of this area should be reviewed by considering the ecology of the target species.

**TABLE 10. ECOLOGICAL CHARACTERISTICS OF FOCAL FISHERIES SPECIES (THEIR INTRINSIC VULNERABILITY TO FISHING PRESSURE, KEY HABITATS, AND MOVEMENT PATTERNS) AND IMPLICATIONS FOR THE DESIGN OF SPATIAL MANAGEMENT MEASURES.** Where spatial management areas should include the key habitats used by focal species, and spatial management areas should be more than twice the size of the home range of focal species (in all directions: Green et al. 2014b). Species whose movement patterns (e.g. spawning migrations or longer term movements) are larger than the size of the spatial management area will only be afforded partial protection. However, these areas can provide benefits for wide-ranging species if they protect their core areas of use or specific locations where individuals aggregate and become especially vulnerable to fishing mortality (e.g. fish spawning areas: Green et al. 2014b).

| Family | Scientific Name (Palauan Name) | Intrinsic Vulnerability to Fishing[1] | Key Habitats to be Included in Spatial Management Areas[2] | Movement Patterns[3] (linear distance in km.) | Recommended Minimum Size of Key Habitats in Spatial Management Areas (linear distance in km.)[3] |
|---|---|---|---|---|---|
| Acanthuridae (Surgeon fishes) | *Naso unicornis* (Chum) | High | Channels, moats, lagoons, and seaward reefs, particularly areas of strong surge. Spawn on outer reef edges. Depths of 1 to 80m. | Home ranges are <1km. (0.6mi.) | 2km. (1.2mi.) should protect this species most of the time |
| Carangidae (Jacks) | *Caranx ignobilis* (Eropk) | High to Very High | Adults range widely over the reef, occurring primarily on seaward reefs. Juveniles occur over sandy inshore bottoms, and use estuaries as nursery habitats. Spawn on shallow seaward reefs and offshore banks. Depths to 80m. | Ontogenetic shifts are >3km. (1.9mi.)<br>Core areas of use are <5km. (3.1mi.)<br>Long term movements are <20-300km. (12 to 186mi.) | 10km. (6mi.) should protect this species most of the time (for ontogenetic shifts and core areas of use), but not during longer term movements |
| Epinephelidae (Groupers) | *Epinephelus fuscoguttatus* (Meteungerel'temekai) | Medium to High | Lagoon pinnacles, channels and outer reef slopes, generally in areas of rich coral growth and clear water. Spawn on seaward end of channels. Depths of 1 to 60m. | Spawning migrations are <30km. (18.6mi.). No home range data is currently available. Until this data becomes available, the closest proxies to use may be other large congeneric species (e.g. *E. tauvina, E. coicoides, E. malabaricus, E. tukula*) where: home range/core areas of use are <3 to <5km. (1.9 to 3.1mi.); and long-term movements are <10 to 20km. (6 to 12mi.) | 10km. (6mi.) should protect this species most of the time (for home ranges and core areas of use), but not during spawning migrations or longer term movements |
| | *Epinephelus polyphekadion* (Ksau'temekai) | Medium to High (if same as *E. fuscoguttatus*) | Clear waters of lagoon and seaward reefs, generally in areas of rich coral growth. Spawn on seaward end of channels. Depths of 1 to >46m. | Spawning migrations are <40km. (25mi.)<br>No home range data is currently available. Until this data becomes available, the closest proxies to use may be other large congeneric species (*e.g. E. tauvina, E. coicoides, E. malabaricus, E. tukula*) where: home range/core areas of use are <3 to <5km. (1.9 to 3.1mi.); and | 10km. (6mi.) should protect this species most of the time (for home ranges and core areas of use), but not during spawning migrations or longer term movements |

| | | | | | |
|---|---|---|---|---|---|
| | | | | long term movements are <10 to 20km. (6 to 12mi.) | |
| | *Plectropomus areolatus* (Black Tiau) | High | Coastal, lagoon and seaward reefs. Spawn on seaward end of channels. Depths of 2 to >20m. | Home ranges are <1km. (0.6mi.)<br>Spawning migrations are <30km. (18.6mi.) | 2km. (1.2mi.) should protect this species most of the time (home ranges), but not during spawning migrations |
| | *Plectropomus laevis* (Mokas) | High to Very High | Adults inhabit clear lagoon and seaward reefs in areas of rich coral growth. Juveniles occur in relatively turbid areas of deep lagoons. Depths of 4 to at least 90m. | No data is currently available for this species. Until this data becomes available, the closest proxy to use may be *P. areolatus* where: home ranges are <1km. (0.6mi.); and spawning migrations are <30km. (18.6mi.). | 2km. (1.2mi.) should protect this species most of the time (home ranges), but not during spawning migrations |
| Epinephelidae (Groupers) cont. | *Plectropomus leopardus* (Red Tiau) | Medium to High | Coastal and lagoon reefs. Depths of 3 to 100m. | Home ranges are <3km. (1.9mi.).<br>Spawning migrations are <10km. (6 miles). | 6km. (3.7mi.) should protect this species most of the time (home ranges), but not during spawning migrations |
| | *Variola louti* (Baselokil) | Medium to High (if assume similar to *P. leopardus*) | Lagoons, channels and seaward reefs. Adults prefer coral rich growth in clear water below 15m. Juveniles may occur in shallow water (i.e. 4m.). Depths of 3 to 240m. | Home ranges are <3km. (1.9mi.) | 6km. (3.7mi.) should protect this species most of the time |
| Labridae (Wrasses) | *Cheilinus undulatus* (Maml) | High to Very High | Adults occur along steep outer reef slopes, channel slopes, and occasionally on lagoon reefs. Juveniles occur in coral-rich areas of lagoon reefs, particularly among thickets of staghorn *Acropora* corals. Spawn in a range of habitats (i.e. outer reef shelf edges or adjacent to exposed reef passes near steep drop-offs). Depths 2 to at least 60m. | Home ranges are mostly <10km. (6mi.) | 20-24km. (12-15mi.) should protect this species most of the time |
| Lujanidae (Snappers) | *Lutjanus bohar* (Kedesau) | High to Very High | Exposed seaward reefs and adjacent lagoon and channel waters. Tends to be more abundant around atolls than around high islands. Spawn along outer reef slopes. Depths of 4 to 180m. | No data is currently available. Until this data becomes available, the closest proxy to use may be *L. rivulatus* where:<br>Core area of use are <3km. (1.9mi.)<br>Long term movements are <200km. (124mi.) | 6km. (3.7mi.) should protect this species most of the time (for core areas of use) but not during longer term movements |
| | *Lutjanus gibbus* (Keremlal) | High (if assume less than *L. bohar*) | Adults prefer deeper lagoons, passes and seaward reefs, but occasionally occur on outer reef flats. Juveniles inhabit seagrass beds and mixed sand and coral habitats of shallow sheltered reefs. Spawn along outer reef slopes. Depths of 1 to 150m. | No data is currently available. Until this data becomes available, the closest proxy to use may be *L. rivulatus* where:<br>Core area of use are <3km. (1.9mi.)<br>Long term movements are <200km. (124mi.) | 6km. (3.7mi.) should protect this species most of the time (for core areas of use) but not during longer term movements |
| Lethrinidae (Emperors) | *Lethrinus olivaceus* (Melangmud) | Medium | Sandy bottoms of lagoons and seaward reefs (outer reef slopes). Spawn along the edge of the reef. Depths of 1 to 20m. | No data is currently available. Until this data becomes available, the closest proxy to use may be *L. miniatus* where:<br>Core area of use are <5km. (3.1mi.)<br>Long term movements are <200km. (124mi.) | 10km. (6.2mi.) should protect this species most of the time (for core areas of use) but not during longer term movements |
| | *Lethrinus xanthochilus* Mechur) | Medium (if assume similar to *L. olivaceus*) | Shallow lagoon areas of mixed coral rubble and sand as well as seagrass beds. Sand and rubble bottoms near reefs. Depths of 5 to 30m. | No data is currently available. Until this data becomes available, the closest proxy to use may be *L. miniatus* where:<br>Core area of use are <5km. (3.1mi.)<br>Long term movements are <200km. (124mi.) | 10km. (6.2mi.) should protect this species most of the time (for core areas of use) but not during longer term movements |

**TABLE 10. Cont.**

| Family | Scientific Name (Palauan Name) | Intrinsic Vulnerability to Fishing[1] | Key Habitats to be Included in Spatial Management Areas[2] | Movement Patterns[3] (linear distance in km.) | Recommended Minimum Size of Key Habitats in Spatial Management Areas (linear distance in km.)[3] |
|---|---|---|---|---|---|
| Scaridae (Parrofishes) | *Bolbometopon muricatum* (Kemedukl) | High to Very High | Adults inhabit clear outer lagoon, outer reef flat and seaward reefs. Juveniles and newly recruited individuals occur in coral-rich sheltered lagoonal habitats and inshore reefs, particularly among thickets of staghorn *Acropora* corals. They progressively colonize more exposed habitats with increasing size[2]. Spawn along outer reef edges. Depths 1 to 40m. | Home ranges are <10km. (6mi.) | 20km. (12mi.) should protect this species most of the time |
| | *Cetoscarus oscellatus (*previously *C. bicolor)* (Beadel) | High to Very High | Clear lagoon and seaward reefs. Adults prefer the upper reaches of steep coral slopes. Depths of 1 to 30m. | No data is currently available. Until this data becomes available, the closest proxy to use may be *S. rubroviolaceous* where: Home ranges are <2km. (1.2mi.) Long term movements are <5km. (3.1mi.) | 4km. (2.5mi.) should protect this species most of the time (for home ranges) but not during longer term movements |
| | *Chlorurus microrhinos* (Otord) | Medium | Lagoon, sheltered and seaward reefs. Depths of 2 to 35m. | Home ranges are <3k (1.9m.) | 6km. (3.7mi.) should protect this species most of the time |
| | *Hipposcarus longiceps* (Ngyoach) | Low to Medium | Adults and sub adults inhabit sandy bottoms near lagoon and seaward reefs. Juveniles occur among coral rubble of lagoon patch reefs. Depths of 2 to 40m. (or more). | No data is currently available. Until this data becomes available, the closest proxy to use may be *S. ghobban* where: Home ranges are <2km. (1.2mi.) Long term movements <6km. (3.7mi.) | 4km. (2.5mi.) should protect this species most of the time (for home ranges), but not during longer term movements |
| | *Scarus rubroviolaceus* (Rekruk) | Medium (if assume similar to other large *Scarus* spp.) | Seaward reefs (outer reef slopes). Prefers rocky bottoms, particularly boulder-strewn slopes. Depths of 1 to >30m. | Home ranges are <2km. (1.2mi.) Long term movements are <5km. (3.1mi.) | 4km. (2.5mi.) should protect this species most of the time (for home ranges), but not during longer term movements |
| Siganidae (Rabbitfishes) | *Siganus canaliculatus* (Meyas) | Medium (estimate – no values available for this family) | Lagoons, coastal reefs and bay, but primarily on seagrass beds. Depths to 4m. | No data is currently available. Until this data becomes available, the closest proxy to use may be *S. fuscens* where: Home ranges are <3km. (1.9mi.) | 6km. (3.7mi.) should protect this species most of the time. |

[1] Vulnerability Index from Abesamis et al. 2014 (where species are not listed, we used the closest available species as a guide).
[2] All habitat information is from Allen et al. 2003 and Myers 1999, except for the information on juvenile *B.muricatum* (which is from Aswani and Hamilton 2004 and R. Hamilton *pers. comm.)* and *C. ignobilis* (which is from Smith and Parrish 2002). Additional information on spawning habitats is from Colin 2009 and the IUCN Red List website (http://www.iucnredlist.org) (NB: the information on spawning areas may need to be refined.)
[3] All movement data and recommended minimum size of spatial management areas are from Green et al. 2014b, except for more recent data for *C. undulatus* from Weng et al. 2015.

**TABLE 11. POTENTIAL BENEFITS OF EXISTING AND PROPOSED SPATIAL MANAGEMENT MEASURES TO EACH FOCAL FISHERIES SPECIES** These categories are based on the ecology of each species (Table 10) and the characteristics of each zone including: the relative protection afforded by each type of zone and the habitat types located within the zone; and how much of each habitat type is included in each zone**.** Where: dark green=fully-protected no-take zone; light green=no-take zone with catch-and-release sport fishing; dark blue=subsistence fishing zone; light blue=commercial fishing zone; and orange=crab closure zone.

| **Family and Species** | **1. Ngaruangel Nature Reserve** (Existing permanent NTZ, no access) | **2. Kayangel Subsistence Fishing Zone** (Existing) | **3. Kayangel and Ngarchelong Subsistence Fishing Zone** | **4. Velasco Commercial Fishing Zone** (Proposed) | **5. Ngkesol/ Ngerael No-Take Zone** (Proposed NTZ, with catch-and-release sport fishing for *Caranx ignobilis* only) | **6. Ebiil Channel Conservation Area** (Existing NTZ) | **7. Matul Crab Closure Zone** (proposed NTZ for mangrove crab; other subsistence fishing allowed) | **8. Ngarchelong Subsistence Fishing Zone** (Proposed for reef; commercial only outside reef) |
|---|---|---|---|---|---|---|---|---|
| **Acanthuridae (Surgeonfishes)** | | | | | | | | |
| *Naso unicornis* (Chum) | HIGH | SOME | SOME | SOME | HIGH | HIGH | NONE | SOME |
| **Carangidae (Jacks)** | | | | | | | | |
| *Caranx ignobilis* (Eropk) | SOME | SOME | SOME | SOME | SOME | SOME | NONE | SOME |
| **Epinephelidae (Groupers)** | | | | | | | | |
| *Epinephelus fuscoguttatus* (Meteungerel'te mekai) | SOME | SOME | SOME | SOME | SOME | SOME | NONE | SOME |
| *Epinephelus polyphekadion* (Ksau'temekai) | SOME | SOME | SOME | SOME | SOME | SOME | NONE | SOME |
| *Plectropomus areolatus* (Black Tiau) | SOME | SOME | SOME | SOME | SOME | SOME | NONE | SOME |
| *Plectropomus laevis* (Mokas) | SOME | FEW | FEW | SOME | SOME | SOME | NONE | SOME |
| *Plectropomus leopardus* (Red Tiau) | HIGH | SOME | SOME | SOME | HIGH | SOME | NONE | SOME |
| *Variola louti* (Baselokil) | HIGH | SOME | SOME | SOME | HIGH | SOME | NONE | SOME |
| **Labridae (Wrasses)** | | | | | | | | |
| *Cheilinus undulatus* (Maml) | SOME | SOME | SOME | SOME | HIGH | SOME | NONE | SOME |
| **Lujanidae (Snappers)** | | | | | | | | |
| *Lutjanus bohar* (Kedesau) | SOME | SOME | SOME | SOME | SOME | SOME | NONE | SOME |
| *Lutjanus gibbus* (Keremlal) | SOME | SOME | SOME | SOME | SOME | SOME | NONE | SOME |

TABLE 11. Cont.

| Family and Species | 1. **Ngaruangel Nature Reserve** (Existing permanent NTZ, no access) | 2. **Kayangel Subsistence Fishing Zone** (Existing) | 3. **Kayangel and Ngarchelong Subsistence Fishing Zone** (Proposed) | 4. **Velasco Commercial Fishing Zone** (Proposed) | 5. **Ngkesol/ Ngerael No-Take Zone** (Proposed NTZ, with catch-and-release sport fishing for *Caranx ignobilis* only) | 6. **Ebiil Channel Conservation Area** (Existing NTZ) | 7. **Matul Crab Closure Zone** (proposed NTZ for mangrove crab; other subsistence fishing allowed) | 8. **Ngarchelong Subsistence Fishing Zone** (Proposed for reef; commercial only outside reef) |
|---|---|---|---|---|---|---|---|---|
| **Lethrinidae (Emperors)** | | | | | | | | |
| *Lethrinus olivaceus* (Melangmud) | SOME | SOME | SOME | SOME | SOME | SOME | NONE | SOME |
| *Lethrinus xanthochilus* Mechur) | SOME | SOME | SOME | SOME | SOME | SOME | NONE | SOME |
| **Scaridae (Parrofishes)** | | | | | | | | |
| *Bolbometopon muricatum* (Kemedukl) | SOME | SOME | SOME | SOME | HIGH | SOME | NONE | SOME |
| *Cetoscarus oscellatus* (previously *C. bicolor)* (Beadel) | HIGH | SOME | SOME | SOME | HIGH | HIGH | NONE | SOME |
| *Chlorurus microrhinos* (Otord) | HIGH | SOME | SOME | SOME | HIGH | SOME | NONE | SOME |
| *Hipposcarus longiceps* (Ngyoach) | HIGH | SOME | SOME | SOME | HIGH | HIGH | NONE | SOME |
| *Scarus rubroviolaceus* (Rekruk) | HIGH | SOME | SOME | SOME | HIGH | HIGH | NONE | SOME |
| **Siganidae (Rabbitfishes)** | | | | | | | | |
| *Siganus canaliculatus* (Meyas) | NONE | NONE | NONE | NONE | NONE | NONE | NONE | SOME |

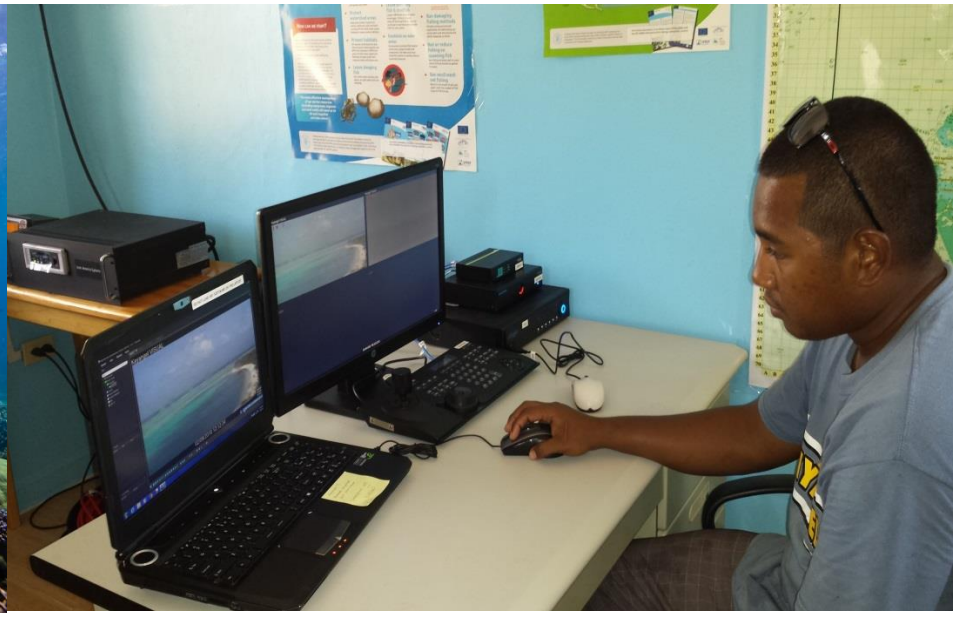
## 3.6 INTEGRATION OF SPATIAL AND NON-SPATIAL MANAGEMENT MEASURES TO ACHIEVE GOALS

The fishery management measures include both spatial and non-spatial measures that should work together, in an integrated way, to support the rebuilding of fish populations over time.

- The permitting measures are designed to limit access by non-residents and to focus activities to zones where those uses can be sustained over the long term. Ensuring that resource users obtain permits and are familiar with the zones and the allowed activities will be critical for success. For example, ensuring that subsistence fishing is occurring in the proper zones, with daily catch limits and/or minimum size limits for focal species, is enforced will work in a complementary way to help rebuild focal species populations.
- Large, well-designed and managed NTZs can be effective management tools for some (but not all) fisheries species, since some species are wide ranging and will move outside these areas where they can be fished. Therefore, integrating management of different types of zones, along with non-spatial management measures, will be particularly important for wide-ranging species that are unlikely to stay within the boundaries of NTZs. Species that move over a distance to spawning grounds or in their home range may need temporal closures.
- For species that do not move far and are likely to stay within well-designed and managed NTZs (e.g. *Naso* but also small groupers, parrotfish, and surgeonfish), these NTZs are likely to provide substantial benefits to surrounding fisheries by allowing individuals to grow to their maximum size, density/biomass, and reproductive potential, leading to enhanced larval supply in fishing zones (particularly within 15km. of the

NTZ: Green et al. 2014b). Fisheries are also likely to benefit from spillover of adults and juveniles in fishing zones that are close to the boundary with NTZs (with the most benefits within a few kilometers of the NTZ).

- The benefits to focal fisheries species within fishing zones will depend on several factors including their vulnerability to fishing pressure (Table 10), how much fishing is occurring in each zone, and the relative benefits of non-spatial management measures. Therefore, the relative contribution of each zone to achieving fisheries objectives (e.g. increasing SPR to 20%) for each focal species will depend upon several factors that need to be integrated in an overall management plan for each species (including the size of the zone and its likely contribution to fisheries management).
- Outright bans on fishing for some species and minimum size limits are aimed at removing fishing pressure completely or fishing pressure on immature individuals for at least a few years to provide the opportunity for their spawning biomass to increase. Some of these species (e.g. smaller parrot fish) are relatively productive and fast-growing, and their spawning biomass should show increases over a few years. However, some of these species are slower-growing (e.g. current banned like bumphead and larger groupers) and may take longer than three years for their spawning biomass to recover to desired thresholds. Monitoring of the size distribution of these focal species in the field, both inside and outside of NTZ, at the three-year interval will help to determine whether populations are recovering and whether these types of regulations should be continued, adaptively modified, or repealed.



Left to Right: © TNC Steven Victor) Ian Shive

# 4.0 COMPLIANCE AND ENFORCEMENT

## 4.1 IMPORTANCE OF COMPLIANCE AND ENFORCEMENT

Monitoring, control and surveillance (MCS) is focused on compliance to fishery management measures. The monitoring program gathers information on the fish populations and fishery that is used to develop and assess appropriate management measures, while surveillance is used to ensure these controls are complied with (Bergh and Davies 2002).

Community awareness of management measures, rules, and regulations will be important to sustain community support for management. Transparency in enforcement (i.e. application of rules to everyone equally) will be important to ensure trust from fishers and community members on enforcement process.

## 4.2 NORTHERN REEFS COMPLIANCE AND ENFORCEMENT PROGRAM

Compliance and enforcement of the Northern Reefs will be done jointly through the Kayangel Department of Natural Resources and Enforcement and Ngarchelong Department of Natural Resource and the Division of Fish & Wildlife Protection. There will be a joint enforcement authority in place whereby national officers, rangers from each respective state, will be given authority to cross enforce across the boundaries of the Northern States. This authority only applies to jurisdictions of National and the two states through an agreement between the states and National.

A series of enforcement improvements are being made, such as the installation of long-range surveillance camera, potential radar support, and further training and improvement in enforcement coordination within the states, across states, and in coordination with Division of Fish & Wildlife Protection of the Bureau of Maritime Security and Fish and Wildlife Protection of the Ministry of Justice.

It is anticipated that long-term success of enforcement will be supported by an increase in compliance from the fishermen. Focused education and awareness trainings on management rules, regulations, and benefits will be conducted and continue to be provided to ensure support from the fishermen and community. The Northern Reef Fisheries Cooperative members are expected to play a vital role in enforcement and compliance by acting as extra eyes in the water and bridging awareness between fishers

### 4.3 FINES AND PENALTIES

Graduated sanctions ensure compliance with the rules and regulations through a series of progressively stricter penalties for the number and scale of infractions. For the Northern Reefs system of management, all infractions, whether violations of permit requirements, fishing during closed seasons, or in closed areas, take of disallowed species and take of fish under the minimum size limit, will be treated equally under the law. The following sanctions will apply:

#### TABLE 12. PROHIBITED ACTIVITIES IN THE STATES RULES AND REGULATIONS

| PROHIBITED ACTIVITY | FINE |
|---|---|
| Fishing without a permit – subsistence fishing | $50.00 |
| Fishing without a permit – all other fishing permit | $200.00 |
| Harvesting, taking, or possessing species on moratorium | $500.00 |
| Operating or owning an unregistered boat | $150.00 |
| Operating or owning a commercial fishing boat without a license | $500.00 |
| Commercial photography without a permit | $500.00/day |

A person committing a violation of any provisions of the Regulations shall pay fine as indicated in the above table. Each violation must be counted as a separate violation and punished separately.

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# 5.0 ADAPTIVE MANAGEMENT

Fisheries management and the decision-making processes used to ensure sustainable fisheries and healthy ecosystems require multiple levels of information. Science can provide a basic level of understanding regarding the likely impacts and consequences of fishing and management measures. However, marine fisheries are complex systems and our ability to understand the numerous interactions is limited by available data and information that results in a level of uncertainty, which is generally proportional to the lack of information. It is important to consider management actions and the expected resulting changes in stock and ecosystem status as learning exercises intended to be revaluated and refined over time as new information becomes available. Such a process is called ***adaptive management***. Adaptive management (Parma 1998) is an explicit practice that adheres to the following sequence of events:

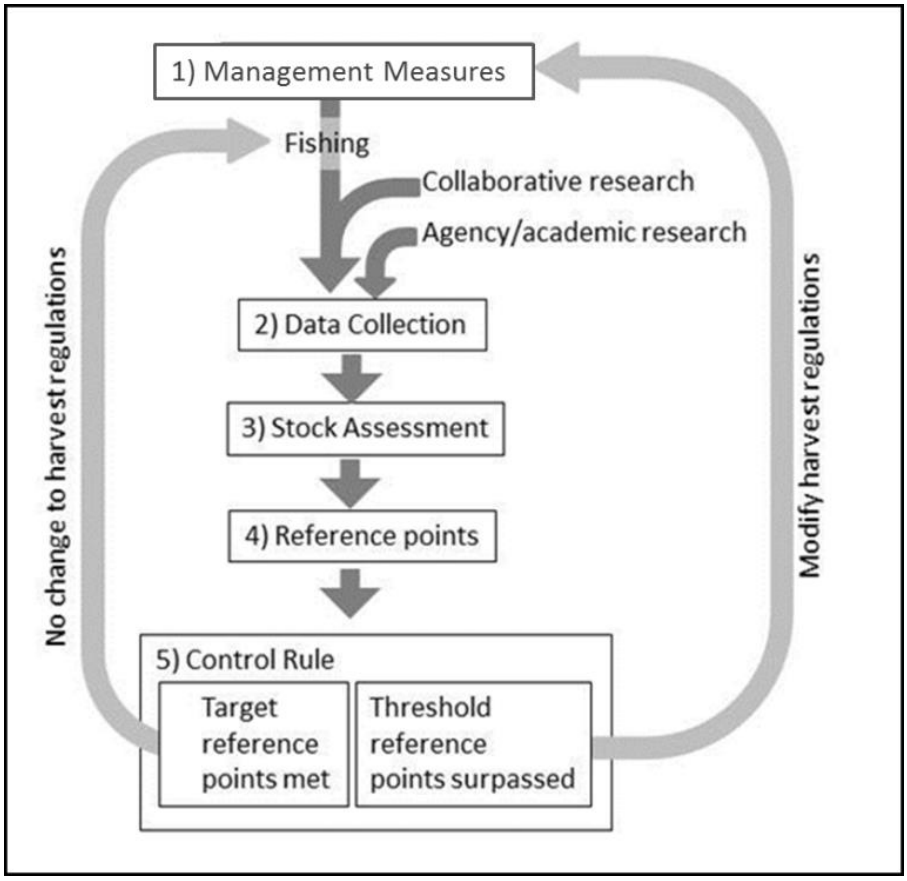
1) collect background information and data on the system to be managed;
2) planning: objective setting and specification of alternative models about the system to be managed;
3) select appropriate management measures and continue monitoring;
4) data collection and implementation of a monitoring plan for measurable indicators; and
5) review process at specified time periods that utilizes a harvest control rule framework to evaluate monitoring information and adjust management measures appropriately.

In the context of this management plan, it is important to recognize that decisions have been made with information that will likely improve over time. For each management action adopted in this plan, a review process is encouraged at a pre-specified time period to review information, consider alternative hypotheses about the success or lack of improvement from a particular action, and decide upon a path forward with regard to adjustment of management measures and monitoring. In Table 1, we provide information on the types of measurable indicators that can be evaluated to determine if the management plan is successful. Table 5 provides the actionable monitoring techniques and a specified time period in which the review and possible adjustment to management measures should take place.

The harvest control rule framework described in section 2D on Fisheries Science and Understanding of Stock Status provides an objective framework for determining appropriate management adjustments to be made using a suite of available management measures. Consider the example of the reef fish Kedesau (*Lutjanus bohar*). Information on Kedesau (step 1 of the adaptive management process) indicated that overfishing was occurring and the stock status of the resource was below the target reference point of SPR 20%. Information on the demographics of the species indicated that the species is vulnerable to harvest before, during, and after the new and full moon. The planning process (step 2) identified the objective of the management system as ensuring that targeted stocks reach a minimum SPR of 20% to ensure a healthy and sustainable fishery. Management measures (step 3) in the form of a minimum size limit of 18 inches and a ban on fishing for two days before and after the new and full moon were agreed upon and implemented. A monitoring system has been put in place (step 4) to collect information on the size structure of the catch in order to understand the relationship between the size structure of the catch and the SPR over time. Within a three-year time period of implementation of these measures, the review process (step 5) will utilize the harvest control rule framework (Figure 6, Table 5) to evaluate available information and determine if the management measures have achieved the stated objectives of the plan. Specifically, scientists will estimate SPR relative to the target of 20%. A review body made up of representative organizations (e.g. Kayangel, Ngarchelong, PCS, TNC, and PICRC) will decide upon the appropriate course of action given the available information.

The following figure summarizes steps 3-5 of the adaptive management framework and is the process by which monitoring data is used to guide decision making (Figure 11)

**FIGURE 11.** The adaptive management process is used to guide decision making that utilizes monitoring data and assessments to inform a control rule approach to adjust management measures



## 5.1 DATA AND MONITORING

To ensure management measures are effectively implemented and meet the specified management targets, it is imperative to continue monitoring and to collect data on a regular basis. The following programs should be prioritized as necessary to understand the impacts of management on the status of fish stocks and the fishery:

1) SCUBA Stereo-Video Sampling: the sampling conducted by PICRC (Lindfield et al. 2015) should be revisited at regular time intervals to evaluate the changes in size structure and density of targeted reef fish over time; and
2) Port Monitoring of Fishery Catch: monitoring of the catch of landed fish into the port of Ollei should be continued on a regular basis. At a minimum, randomized sampling of the size structure of targeted species should be recorded. In addition, total landings by permitted fishing type and effort statistics will allow for analysis that is important to understand the impacts on fishermen and will provide an additional indicator to determine the status of the resource over time.

## 5.2 REVIEW AND DECISION-MAKING PROCESS

On yearly time intervals, or otherwise agreed upon time periods, a review panel will meet to compile existing data, monitoring trends, analyses and other pertinent information. Consideration will be given to ensuring information is reviewed and presented by third party independent scientists and practitioners where appropriate. The review panel shall be comprised of representatives from the following organizations:

> Fishermen from the States of Kayangel and Ngarchelong or members of the Northern Reef Fisheries Cooperative, Palau International Coral Reef Center, Palau Conservation Society, The Nature Conservancy, Bureau of Marine Resources, Division of Fish & Wildlife Protection, Representative from Kayangel Department of Natural Resources and Enforcement and Ngarchelong Department of Natural Resources and Development.

Outcomes from meetings will be documented and compiled in a written report that summarizes key updates to the data and monitoring program, recommended adjustments to any management measure, and methods to ensure effective compliance and enforcement.

## 5.3 PRECAUTIONARY APPROACH

Management actions should be taken to avoid unacceptable or undesirable situations. Numerous indirect and uncontrollable impacts on marine and fisheries systems pose significant threats to achieving desired management outcomes. When uncertainty is high, management actions should be implemented with enhanced precaution such that there are buffers to allow for unforeseen consequences without causing the stock to drop below predetermined thresholds. To be precautionary, decision rules should be objectively prescribed and should be able to be adjusted in a timely and efficient manner. Moreover, decision rules should limit the probability of dropping below a prescribed threshold. For example, in the case of implementing a size limit, the intention is to ensure that the stock never drops below the 20% SPR level. Simply setting a minimum size limit at the level that would theoretically achieve an average of 20% SPR may in fact allow the stock to drop below the threshold. To be precautionary, the minimum size limit should be adjusted higher, or additional measures should be enacted to ensure fishing of legal-sized animals is further reduced through such mechanisms as season closures, spatial closures, or otherwise.

To ensure a precautionary approach is adopted, serious consideration for constant readjustment to management measures should be considered. If management measures are found to be inadequate with regard to the precautionary approach, the following aspects should be considered (FAO 1996):

- modification of the operational targets and constraints;
- re-specification of the procedure to apply management measures;
- further research to reduce critical uncertainties; or
- consideration of more powerful assessment and monitoring methods.

# 6.0 CONCLUSION

The Northern Reefs Fishery Management Plan is the first effort to develop a comprehensive approach towards improving fisheries management, rebuilding depleted fish stocks, and integrating fisheries into the ecosystem protection goals of the PAN process. The declining stocks, proportion of immature fish being caught, and local perceptions have driven a desire for a new management approach. The recommendations in this plan reflect our best understanding of the underlying science, best available monitoring data, and desired goals of the people and communities of Ngarchelong and Kayangel.

Full implementation of this plan with the integrated spatial and non-spatial management measures is essential as the elements are designed to work together in a complementary manner. Public outreach and education will be critical to enhance community support for the permitting, harvest control, and spatial zoning measures. A compliance and enforcement program will also be essential to ensure that these management measures have a chance of meeting the overall fishery and ecosystem goals.

It will also be important to temper expectations and to remember that some fish species and ecosystem components will respond faster and better to these management actions than others. Some of the focal fish species are slow-growing or very mobile, and their populations may not rebuild as quickly as other faster-growing and more sedentary species. An adaptive management approach, supported by new monitoring data, will be needed to assess whether the goals are being met or management measures need to be revised.

With this Fisheries Management Plan, the communities and people of the Northern Reefs of Palau have taken a significant step towards rebuilding their fisheries, protecting their ecosystems, and ensuring the long-term sustainability of their resources for future generations.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