# Value of Ecosystem Services from Coral Reef and Seagrass Habitats in CNMI

## Final Report

*Prepared for*
Bureau of Environmental and Coastal Quality's Division of Coastal Resources Management (BECQ-DCRM)
Commonwealth of the Northern Mariana Islands (CNMI)
Saipan

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**September 2019**

Financial Assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office for Coastal Management, National Oceanic and Atmospheric Administration.

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## ABREVIATIONS

| | |
|---|---|
| BEC | Blue Earth Consultants |
| BECQ | Bureau of Environmental and Coastal Quality |
| CNMI | Commonwealth of the Northern Marina Islands |
| CPI | Consumer Price Index |
| CVM | Contingent Valuation Method |
| DCRM | Division of Coastal Resources Management |
| DFW | Division of Fish and Wildlife |
| EPA | Environmental Protection Agency |
| ERG | Eastern Research Group, Inc. |
| FY | Fiscal Year |
| GIS | Geographical Information System |
| MPA | Marine Protected Area |
| NCCOS | National Centers for Coastal Ocean Science |
| NOAA | National Oceanic and Atmospheric Administration |
| PPP | Purchasing Power Parity |
| SWAN | Simulating Waves Nearshore |
| USD | U.S. Dollars |
| WTP | Willingness to Pay |

# Executive Summary

This report provides an economic valuation of seagrass and coral reef ecosystems in the Commonwealth of the Northern Mariana Islands (CNMI) to improve understanding of benefits, support updating the existing mitigation hierarchy, and address growing development pressures that may affect seagrass and coral habitats. Specifically, the project had the following objectives:

- Compiling existing information on the economic value of coral reefs and seagrass habitats in the Pacific region;
- Estimating the spatially explicit total economic value of coral reef ecosystems in Saipan, Rota, and Tinian; and
- Estimating the spatially explicit total economic value of seagrass habitats in Saipan.

The ecosystem services of seagrass and coral addressed in this report include:

- Commercial fishing,
- Non-commercial fishing by residents,
- Tourism and recreation,
- Amenity/property value,
- Research,
- Biodiversity, and
- Coastal protection

This report builds on and expands the van Beukering, et al., 2006 study commissioned by CNMI. The prior study, however, covered only coral reefs surrounding Saipan. This report assesses values of coral reefs ecosystems in Saipan, Rota, and Tinian and seagrass ecosystems in Saipan. Furthermore, this report also covers ecosystem services not covered by the prior work, including the value of biodiversity beyond research uses. The 2006 report, however, also covered a number of items not included in this report. The project covered by the 2006 report included a survey of residents on Saipan that involved collection of choice experiment data; the project covered by this report did not include a similar survey. The 2006 report also discussed considerations of sustainable financing for Marine Protected Areas (MPAs), an area not addressed under this project.

This report updates and expands the 2006 analysis. In developing these estimates, the report relies on benefit transfer methods to calculate the values of ecosystem services. Benefit transfer involves taking value estimates from “study sites” where time and effort was spent to develop valid estimates and applying those estimates to “policy sites” where estimates are not available; in this project, CNMI is the policy site. Benefit transfers offer the ability to develop estimates of the value of potential improvements at significantly less cost and time than developing primary estimates.

Table ES-1 offers a summary of the estimates provided in this report. Across all ecosystem services, the coral reefs of CNMI generate $104.5 million annually in economic value and the seagrass of Saipan generates an additional $10.3 million in value. ***In total the coral reefs and seagrass in CNMI generate an annual value of $114.8 million***.

Figure ES-1 provides the distribution of the total estimated value (coral reefs plus seagrass) over the ecosystem services. As Figure ES-1 demonstrates, the predominant values are producer surplus generated by foreign tourists (64 percent of the total) and coastal protection (18 percent); combined these two generate 83 percent of the total annual value for coral and seagrass in CNMI.[1]

**Table ES-1. Summary of Estimates of Ecosystem Services for Coral Reefs and Seagrass in CNMI**

| Ecosystem Service | Coral Reefs | Seagrass | Total Value |
|---|---|---|---|
| Commercial Fishing | $688,600 | $43,600 | $759,200 |
| Non-commercial fishing | $731,800 | $46,300 | $778,100 |
| Amenity-Based Value | $4,912,228 | $926,672 | $5,838,900 |
| Foreign Tourism | $65,580,600 | $8,059,400 | $73,640,000 |
| Recreation | $9,090,700 | $1,117,200 | $10,207,900 |
| Biodiversity – Research Value | $1,119,700 | $140,700 | $1,260,400 |
| Biodiversity – Non-research | $1,179,900 | [a] | $1,179,900 |
| Coastal Protection | $21,202,415 | [a] | $21,202,415 |
| **Annual Total Values** | **$104,505,943** | **$10,333,872** | **$114,839,815** |

[a] Not measured due to insufficient prior research to provide reliable estimates to use in calculating value.

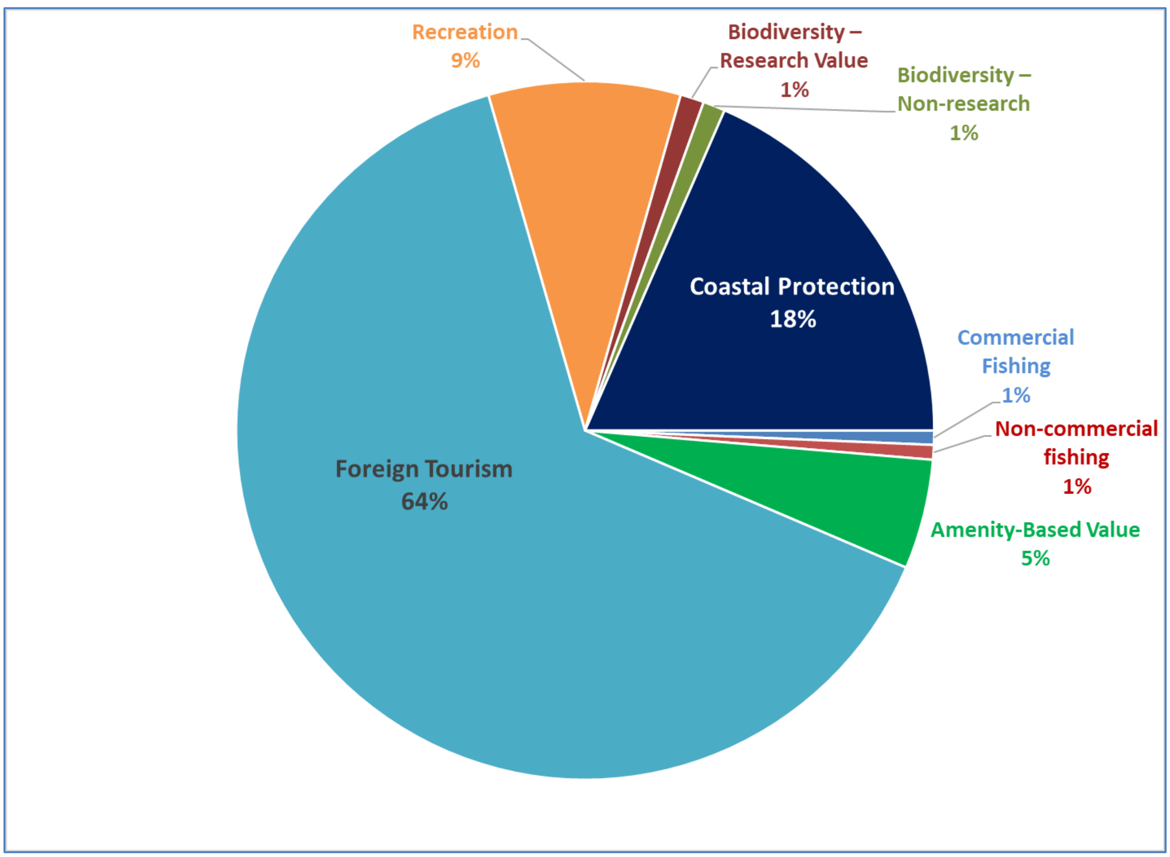



**Figure ES-1. Distribution of Estimated Ecosystem Service Values**

[1] Some rounding error occurs in the 83 percent calculation.

To support continued analysis and updates to further identify economic values of the many benefits that coral and seagrass provide to people, the economy, and the environment, Table ES-2 provides a summary of Easter Research Group's (ERG) recommendations for future research needs to allow the estimates in this report to be updated on a regular basis and to expand on these estimates. These recommendations are discussed as "next steps" within each section of the report.

**Table ES-2. Recommendations for Maintaining and Expanding the Estimates from This Report.**

| Ecosystem Service | Recommended Next Steps |
|---|---|
| Commercial Fishing | • Update the estimates using new data on an annual basis. Each key data input (landings, price per pound, etc.) will have new data annually. Using those new data will allow for more current numbers.<br>• Perform additional research using the "high catch rate" period to estimate value. This report has provided a reasoned argument for using that time period, but we have not performed additional in-depth research into using that assumption.<br>• Perform research into the relative productivity of coral reefs and seagrass in terms of fisheries and adjust the distribution between the two habitats accordingly. The approach used by ERG (based on percentage of total habitat) assumes equal productivity. |
| Non-commercial fishing | • ERG recommends that the next step for this ecosystem service would be to repeat the survey and associated analysis conducted for Guam for the 2006 report for CNMI. This would allow CNMI to develop a more precise and more relevant estimate for this and other ecosystem services.<br>• As with commercial fishing, BECQ-DCRM should perform research into the relative productivity of coral reefs and seagrass in terms of fisheries and adjust the geospatial distribution and associated values between the two habitats accordingly. These values can be used to further inform management priority planning dialogs. |
| Amenity-Based Value | • ERG recommends that BECQ-DCRM perform a hedonic property valuation analysis to develop estimates of how property values vary with proximity to coral reefs and seagrass (or, alternatively, proximity to the shoreline). This would replace the study used as a basis for the estimate here and provide estimates that are based on CNMI to support future updates |
| Foreign Tourism | • In order to keep these estimates up to date, CNMI should continue to update the values for the dollars spent per person from different countries and the number of annual trips taken by visitors from those countries.<br>• CNMI should spend additional time and effort to identify the places that tourists visit that are related to coastal habitats. CNMI should determine which locations are most popular to allow for better spatial distribution of the estimates. |
| Recreation | • Update the costs per activity and the numbers of activities on a regular basis.<br>• Map the locations where the activities occur based on input from businesses that perform these activities; this would allow for better spatial distribution of the estimates. One approach could be to use participatory GIS methods with the businesses to allow them to identify activity locations and frequencies of activities at those locations.<br>• Perform a WTP study to estimate the value that people place on these specific activities. The study used here is based on Guam. Using a choice experiment approach would allow for placing values on the activity based on conditions that are seen in different areas (e.g., presence or abundance of certain specie) and hence more fine-tuned estimates of WTP. |
| Biodiversity – Research & Biodiversity – Non-research | • ERG recommends that BECQ-DCRM perform additional research on approaches to value research and non-research biodiversity values. ERG was able to extract information from prior studies for these estimates, but a study that focused solely on this topic based in CNMI would be warranted. |

| Ecosystem Service | Recommended Next Steps |
| --- | --- |
| Coastal Protection | • Although the study we used to develop these estimates was based on a recent report and developed estimates specific to CNMI, there are areas where BECQ-DCRM can improve on the estimates from the report. Specifically, the study used older data on the building stock on the islands that did not include newer developments. ERG recommends that BECQ-DCRM review the study data source in detail and recreate the analysis using the modeling in study with the most current data available. |

Ultimately, measuring and understanding the benefits – both economic and non-economic – that corals and seagrass provide, will support management and conservation dialogs within CNMI.

# 1.0 Introduction

The Commonwealth of the Northern Mariana Islands (CNMI), made up of 14 islands in the northwestern Pacific Ocean, is home to abundant marine biodiversity and ecosystems that provide valuable services that support sustainable livelihoods, coastline protection, tourism opportunities, and cultural and recreational uses. Coral reef ecosystems on Saipan alone were estimated to provide over $61 million per year in ecosystem services[2] in a 2006 study (van Beukering, et al., 2006). However, CNMI is experiencing increasing pressure for coastal development that could impact these and other marine resources, such as erosion, vessel groundings, and increased runoff of sediment and pollutants from human settlements, industry, and infrastructure; additionally, each of these threats is present in the larger context of global climate change. The Bureau of Environmental and Coastal Quality's Division of Coastal Resources Management (BECQ-DCRM) works to reduce potential environmental impacts from development by protecting resources through regulatory programs (permitting and enforcement) within the CNMI's areas of particular concern, which includes reef, wetland, shoreline, lagoon, mangrove, port and industrial, and coastal hazard zones.

BECQ-DCRM requires robust and up-to-date information about the CNMI's coral reef and seagrass ecosystem values to facilitate resource management planning as well as to support settlement actions between regulatory agencies and the responsible parties and formalize mitigation protocols; however, the last localized natural resource economic valuation in the CNMI took place more than a decade ago and focused solely on coral reefs of Saipan (van Beukering et al., 2006). BECQ-DCRM contracted with Eastern Research Group, Inc. (ERG) and its division Blue Earth Consultants (BEC) to assess the value of the CNMI's coral reef systems and seagrass habitats to provide managers and the public with information to help sustain these important marine ecosystems and support effective development and conservation decisions.

## 1.1 Scope

The purpose of this project was to conduct an economic valuation of seagrass and coral reef ecosystems in the CNMI to support updating the existing mitigation hierarchy and address growing development pressures that may affect seagrass and coral habitats. Specifically, the project had the following objectives:

- Compiling existing information on the economic value of coral reefs and seagrass habitats in the Pacific region;
- Estimating the spatially explicit total economic value of coral reef ecosystems in Saipan, Rota, and Tinian; and
- Estimating the spatially explicit total economic value of seagrass habitats in Saipan.

To accomplish these objectives, this report assesses values of several ecosystem services:

- Commercial fishing,
- Non-commercial fishing by residents,

[2] Ecosystem services can be broadly defined as the benefits humans derive from different aspects of ecosystem structure and function.

- Tourism and recreation,
- Amenity/property value,
- Research,
- Biodiversity, and
- Coastal protection

This report builds on and expands the 2006 study cited above. The prior study, however, covered only coral reefs surrounding Saipan. This report covers coral reefs ecosystems in Saipan, Rota, and Tinian and seagrass ecosystems in Saipan. Furthermore, this report also addresses ecosystem services not covered by the prior work, including the value of biodiversity beyond research uses. The 2006 report, however, also assessed a number of items not included in this report. Specifically, the project covered by the 2006 report included a survey of residents on Saipan that involved collection of choice experiment data; the project covered by this report did not include a similar survey.[3] The 2006 report also discussed considerations of sustainable financing for marine protected areas (MPAs), an area not addressed under this project. To support ongoing analysis, this report also includes recommended next steps to fill data gaps and support expanded eco-valuation efforts, which would benefit from at least decadal updates.

## 1.2 Methods

ERG used benefit transfer methods to calculate the values of ecosystem services in this report. Benefit transfer involves taking value estimates from a “study site” where time and effort was spent to develop valid estimates and applying those estimates to a “policy site” where estimates are not available; in this project, CNMI is the policy site. Benefit transfers offer the ability to develop estimates of the value of potential improvements at significantly less cost (and time) than developing primary estimates.

In transferring the estimates from study sites, it is necessary to adjust the estimates. One basic adjustment that almost always needs to be made is for the change in price levels over time (inflation) and to adjust for differences in regional prices (i.e., adjust for the prices in CNMI relative to the area where the source estimates come from). In most cases, ERG took the values estimated in other studies, adjusted for temporal and regional differences in prices, and applied those to CNMI.

Another consideration is that the spatially explicit valuation requires a per unit of area value (e.g., value per hectare). In a benefit transfer approach, these per unit of area values are often available from other studies. In cases where they are not, we convert to a per unit of area value using the data from Table 1.

**Table 1. Total Areas of Coral Reef and Seagrass Habitat Used in the Analyses**

| Island | Total Coral Reef Habitat ($km^2$) | Total Seagrass Habitat ($km^2$) | Total Habitat ($km^2$) |
|---|---|---|---|
| Saipan | 68.03 | 6.67 | 74.70 |
| Tinian | 16.57 | 0 | 16.57 |
| Rota | 20.75 | 0 | 20.75 |
| **Total** | **105.35** | **6.67** | **112.02** |

Source: NOAA, 2005.

[3] We do, however, draw upon the results of the choice experiment survey in this work since it remains a relevant set of information.

Note: Defined as major benthic cover types for shallow habitats.

We also make a distinction in some services between the current value of the services being provided and the value that could be provided with higher functioning (e.g., healthy) habitats. Specifically, habitats that degrade due to stressors such as overfishing, climate change, or damage will provide lower levels of ecosystem services; this implies that the total value of those services will also decline. A prime example of this is in commercial fishing where the amount of fish caught in CNMI has declined significantly since the 2006 report, but prices have remained approximately the same. This indicates that the value of the services provided by coral reefs have declined over time. Nevertheless, another key consideration should be that, if healthy, coral reefs can provide higher functioning and a larger amount of fish to be caught. Thus, where we can, we attempt to provide estimates of both the current functioning value of the habitats and the potential values that could attained with improved functioning.

Finally, given that our estimates are based on using benefit transfer methods, we have rounded all estimates up to the nearest $100.

## 1.3 Base Layer Maps

As noted above, one purpose of this report is to provide spatially explicit distributions of economic values. To facilitate the mapping process, ERG developed a set of maps that provide the distribution of coral reefs and seagrass areas detailed in Table 1 for Saipan (Figure 1), Rota (Figure 2), and Tinian (Figure 3). We refer to these as the base layer maps. The data from these maps are used to distribute the estimated economic value for several for the ecosystem service that follow in this report.

## 1.4 GIS Analysis Methods

This section describes the technical procedures involved in the GIS analyses and mapping of spatially explicit values of coral reef and seagrass across ecosystem values related to tourism, recreation, amenity, biodiversity, and coastal protection. ERG obtained the best available GIS data on coral reef habitat extent, buildings and parcels, swim zones, dive sites[4], mooring buoys, shoreline access points, and flood scenarios from BECQ-DCRM, and we used the National Oceanic and Atmospheric Administration (NOAA) National Centers for Coastal Ocean Science (NCCOS) marine habitat dataset for seagrass extent. The datasets underwent several preparation, conversion, and processing and analyses steps in spreadsheet and GIS formats. ERG used Esri's ArcGIS Desktop 10.5.1 to develop maps and assess the spatial distribution of coral reefs and seagrass areas in relation to environmental and socio-economic related factors (e.g., buildings and parcels, swim zones, dive sites, mooring buoys, shoreline access points, and coastal flood scenarios). Table 2 provides a summary of ERG's GIS data sources for this analysis.

[4] Note that the mooring buoys dataset also described locations that dive operators use regularly.

Table 2. GIS Data Sources Used by ERG in the Analysis

| GIS Dataset | Data Source |
| --- | --- |
| **Benthic Habitats**[5] | **Saipan:** Received from BECQ-DCRM on September 2018.<br><br>**Rota and Tinian:** NOAA NCCOS. (2005) Benthic Habitat Mapping. https://products.coastalscience.noaa.gov/collections/benthic/e99us_pac/ |
| **Dive Locations and Mooring Buoys** | Pacific Coastal Research & Planning and Dive Rota. (2017) 2017 CNMI Recreational Mooring Buoy Program Enhancement and Maintenance Report. https://dcrm.gov.mp/wp-content/uploads/crm/PCRP_MooringBuoy_FINALREPORT.pdf |
| **Flood Scenarios** | Greene, R. (2017) BECQ 2017 SLR Map Layer Updates: Methodology for Coastal Flood Geoprocessing. |
| **Rota Parcels (2009)** | Received from BECQ-DCRM on September 2018. |
| **Saipan Lagoon Habitat** | Kendall, M.S., B. Costa, S. McKagan and L. Johnston. (2017) Mapping Habitat Change in Saipan Lagoon, CNMI. NOAA Technical Memorandum NOS NCCOS. Silver Spring, MD. |
| **Saipan Buildings** | CNMI Department of Public Lands. (2018) Building Footprints, Dec 2018 Update. |
| **Shoreline Access Points** | BECQ-DCRM. (2016) Shoreline Access. http://becq-dcrm.opendata.arcgis.com/datasets/shoreline-access-cnmi-2016 |
| **Swim Zones** | Received from BECQ-DCRM on September 2018. |
| **Tinian Parcels (2009)** | Received from BECQ-DCRM on September 2018. |

### *1.4.1 Tourism and Recreation*

The socio-economic factors relevant to the analysis for tourism and recreation values include proximity to dive sites, mooring buoys, shoreline access points, swim zones, and Saipan Lagoon. We assigned weights to coral reef and seagrass based on their distance to these socio-economic factors, e.g., higher valued habitat is closer to coral reefs and seagrasses. Both types of ecosystem received a weight of 9 of 18 if it is located within 500 meters of these factors, 5 of 18 if it is located between 500-100 meters, 3 of 18 if it is located between 1000-1500 meters, and 1 of 18 if it is located beyond 1500 meters. ERG used GIS tools, including Buffer, Intersect, Union, Select by Location, and Clip, to develop maps that identify coral reef and seagrass areas relevant to each weight criteria.

### *1.4.2 Amenity-based Property Values and Coastal Protection*

Similar to the 2006 van Beukering, et al. report, ERG characterized CNMI into three parcel layers for both amenity-based property values and coastal protection values analysis:

- **Parcels 1:** Parcels on the coastline (0-100 meters inland)
- **Parcels 2:** Parcels 100-250 meters inland
- **Parcels 3:** Parcels 250-1000 meters inland

[5] The dataset includes both coral and seagrass extent data.

For each of the parcel layer, we distributed the economic values of coral reefs and seagrass by their distance from parcels. Coral reefs and seagrass that are closer to the coast have higher amenity and coastal protection values; we assigned marine habitats that are within 500 meters of parcels with a weight of 7 of 10, areas within 500-1000 meters from parcels with a weight of 2 of 10, and areas beyond 1000 meters from parcels with a weight of 1 of 10. ERG used Buffer, Intersect, Union, Select by Location, and Clip tools to identify the coral reef and seagrass areas relevant to the three parcel layers and then to each weight criteria.

In addition, the GIS parcel dataset for Rota and Tinian included areas with no development, which necessitated a manual removal of selected parcel data. ERG did an overlay of the parcel data and Esri satellite imagery[6] and retained parcels with visible buildings within their boundaries. To further improve the accuracy of the parcel data with visible development, future studies could utilize ground truthing and incorporate field data and local knowledge to minimize errors in the identification of existing buildings on Rota and Tinian.

For the coastal protection analysis, the analysis is only relevant to Saipan because of the geographic limitation of the coastal flood scenarios data. ERG selected buildings categorized as residential, commercial, and hotel for the analysis. Variations on the data quality of GIS features in the Saipan buildings dataset may limit the accuracy of the economic valuation analysis. Specifically, many of the Saipan building features consist of multiple polygons that may be part of multiple properties, which could be a topic of interest for a future update on this work or additional analyses.

### *1.4.3 Biodiversity*

ERG provided an update to the 2006 van Beukering, et al. analysis of the research value of coral reefs. ERG investigated the spatial extent of coral reefs by type of benthic habitat, including living coral, coralline algae, turf algae, and macroalgae. Through the consultation with BECQ-DCRM, we assigned the following weights to each type of benthic habitat: 7 of 10 for living coral, 5 of 10 for coralline algae, 1 of 10 for turf algae, and 1 of 10 for macroalgae. Due to a lack of reliable economic value estimates for biodiversity from seagrass, the economic value of biodiversity from seagrass was not estimated.

[6] Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community. World Imagery. [Accessed Nov 2018].

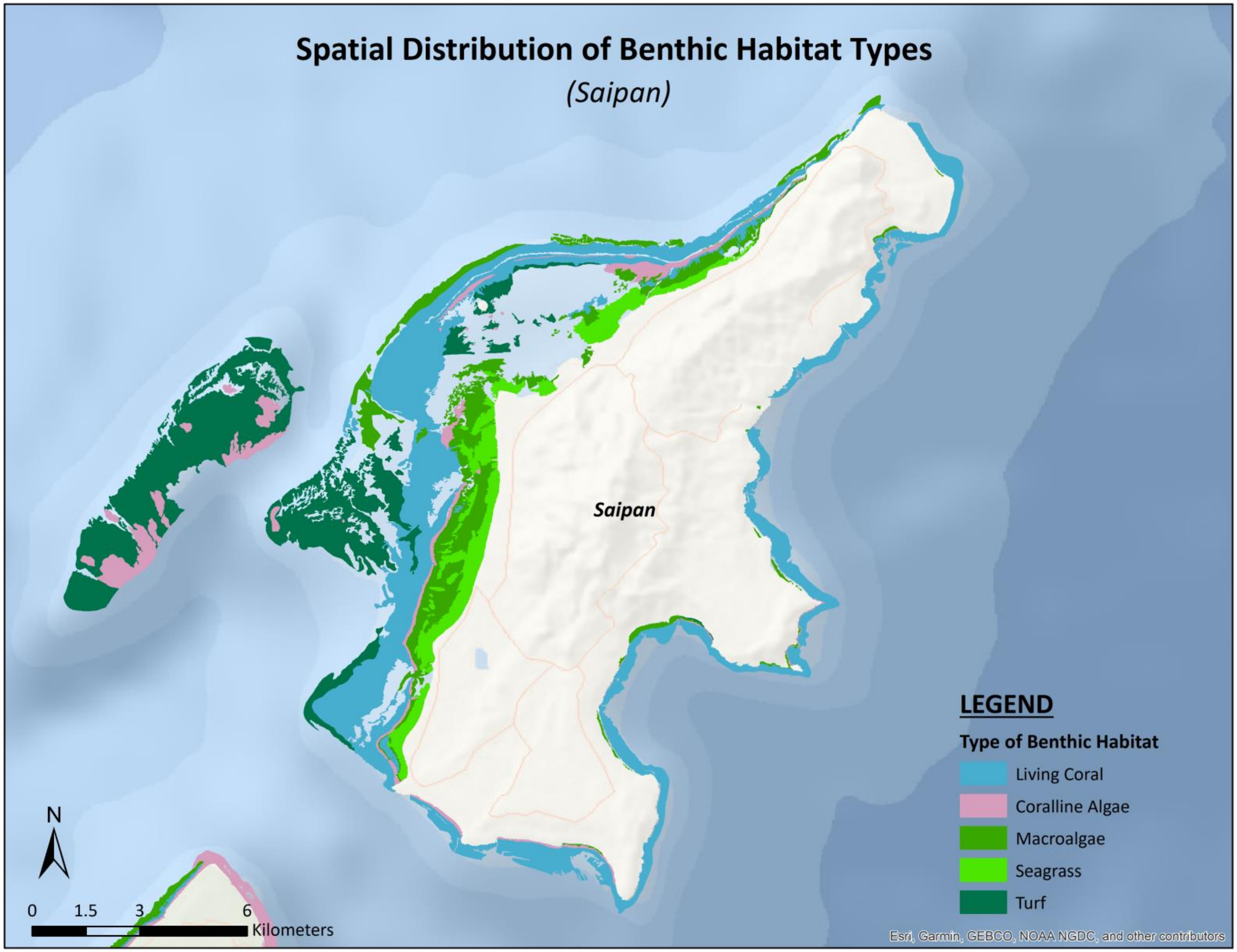



**Figure 1. Distribution of Benthic Habitat Type, Saipan**

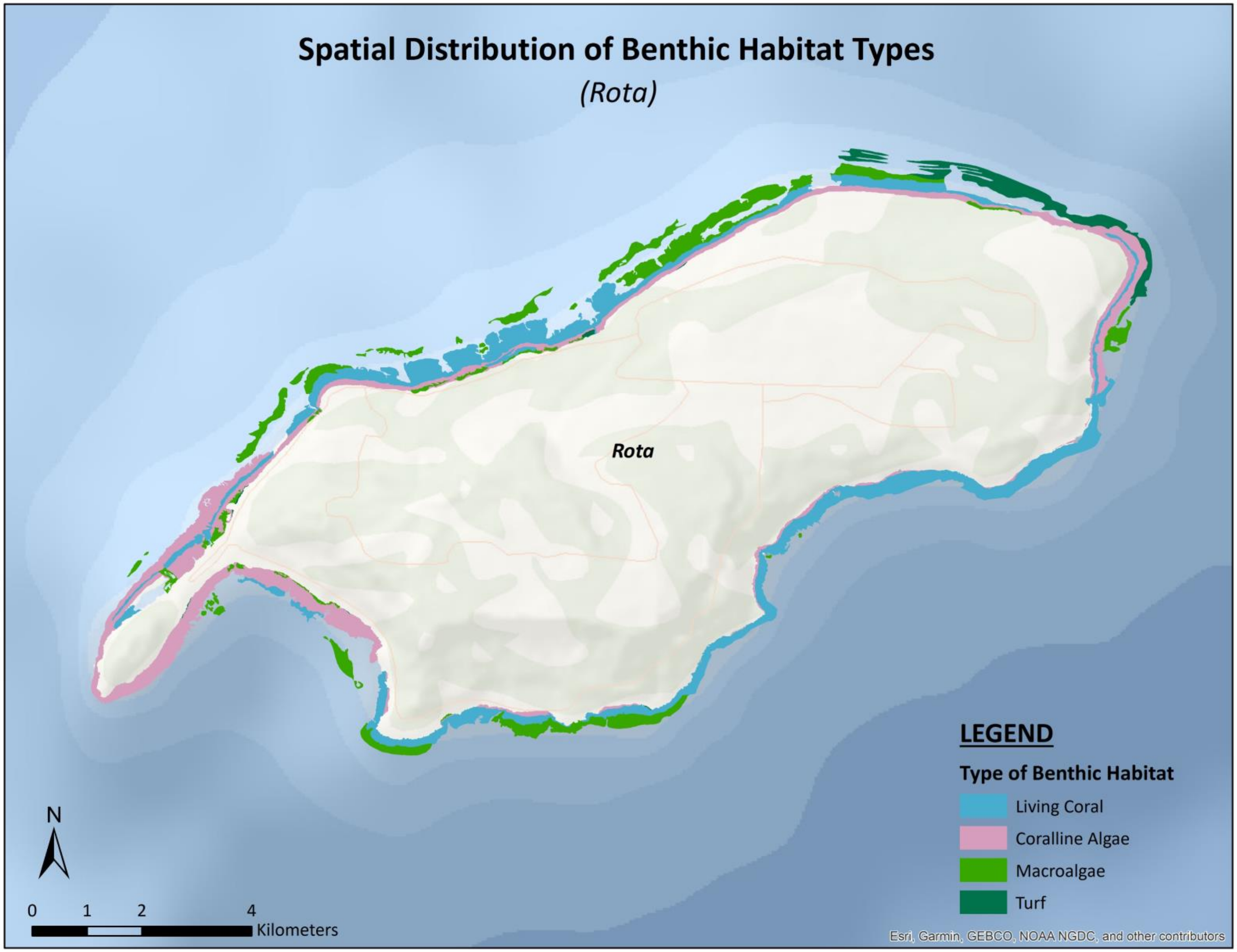



**Figure 2. Distribution of Benthic Habitat Type, Rota**


Figure 3. Distribution of Benthic Habitat Type, Tinian

## 1.5 Comparison to Previous Report

This report was intended to update the 2006 report that provided the value of coral reefs. Overall, this report is broader in terms of habitat, covering the coral reefs of Saipan, Tinian, and Rota and the seagrasses of Saipan. This report also included the non-research value of biodiversity[7] while the 2006 report did not. The 2006 report, on the other hand, included additional components such as a WTP study on CNMI and a consideration of financing mechanisms for MPAs.

On the following pages,

Table 3 provides a comparison to the current report to the 2006 report in terms of the ecosystem service value estimates.

[7] This is the value of having a diversity within and among species.

Table 3. Comparison of Current Report and 2006 Report

| Ecosystem Service | Current Report (Coral Reefs of Saipan, Tinian, and Rota and Seagrasses of Saipan) | | 2006 Report (Coral Reefs of Saipan) | |
|---|---|---|---|---|
| | Estimated Annual Value in Millions | Details | Estimated Annual Value in Millions (Adjusted for Inflation) | Details |
| Commercial Fishing | $0.76 | • Calculated using a five-year average reflecting increased catch rates (and thus, a healthier habitat), adjusting for subsistence fishing, and applying a weighted average 2018 market price for fish. | $0.43 ($0.53) | • Calculated using the most-recent five-year average for catch, adjusting for subsistence fishing, and applying the market price at the time. |
| Non-commercial fishing | $0.77 | • Calculated using a willingness to pay study based on Guam, adjusting to CNMI based on relative purchasing power parity (PPP), and multiplying by the number of households. Estimate reflects a mid-point between an upper and lower bound. | $0.83 ($1.03) | • Calculated using a willingness to pay study based on Guam, adjusting to CNMI based on relative purchasing power parity (PPP), and multiplying by the number of households. Estimate reflects a mid-point between an upper and lower bound. Larger value for 2006 study based on a larger estimated number of households. |
| Amenity-Based Value | $5.8 | • Uses the model that relates property values to distance from shoreline based on Guam that was used for the 2006 study and applies to CNMI (adjusting for PPP) and using the same distribution of properties from the shoreline. | $3.00 ($3.72) | • Uses a model that relates property values to distance from shoreline based on Guam and applies to CNMI (adjusting for PPP) using a distribution of homes from the shoreline. |
| Foreign Tourism | $73.6 | • Includes estimates of both producer and consumer surplus associated with tourism.<br>• Producer surplus – Based on the number of trips and expenditures per person from five countries/areas (Japan, Korea, China, Russia, Guam).<br>• Consumer surplus. Applies the WTP per person for trips to CNMI from 2006 study, adjusted for inflation to the number of trips identified by the producer surplus estimate. | $42.31 ($52.46) | • Includes estimates of both producer and consumer surplus associated with tourism.<br>• Producer surplus – Based on the number of tourist-days spent on CNMI and expenses per day from all source countries.<br>• Consumer surplus. Applies a WTP per person for trips to CNMI based on a meta-analysis to the number of trips from the producer surplus calculation. |

| Ecosystem Service | Current Report (Coral Reefs of Saipan, Tinian, and Rota and Seagrasses of Saipan) | | 2006 Report (Coral Reefs of Saipan) | |
|---|---|---|---|---|
| | **Estimated Annual Value in Millions** | **Details** | **Estimated Annual Value in Millions (Adjusted for Inflation)** | **Details** |
| Recreation | $10.2 | • Includes estimates of both producer and consumer surplus associated with tourism and covers diving, snorkeling, and underwater observation.<br>• Producer surplus. Uses estimates of the number of trips and the price per trip based on estimates provided by operators to BECQ-DCRM staff in early 2019.<br>• Consumer surplus. Uses a WTP study based on Guam for diving, adjusts for inflation, and applies the value to the number of trips in the producer surplus calculation. | $5.77<br>($7.15) | • Includes only producer surplus.<br>• Developed estimates of the number of activities for each category and then applied a WTP value derived in the study for Saipan. |
| Biodiversity – Research | $1.3 | • Based on estimates of the value of coral reefs and seagrass for biodiversity research purposes derived from prior studies. The studies used covered Philippines, French Polynesia, and Australia; data were adjusted for PPP and inflation as needed. | $0.79<br>($0.98) | • Based on the value of grants associated with reef-related research. |
| Biodiversity – Non-research | $1.2 | • Based on estimates of the value of coral reefs and seagrass associated with non-research biodiversity purposes derived from prior studies. The studies used covered Philippines and French Polynesia; data were adjusted for PPP and inflation as needed. | - | • Not included. |
| Coastal Protection | $21.2 | • Taken from a recent USGS study that provided direct estimates for CNMI associated with the value of structure protected and then adjusted for lost value of building contents. | $8.04<br>($9.97) | • Estimated from GIS modeling of wave impacts on Saipan and historical storm trajectories. |
| **TOTALS** | **$114.8** | - | **$61.16<br>($75.84)** | - |

## 2.0 Commercial Fishing

Coral reefs and seagrass provide fertile areas for commercial fish species to forage as well as a nursery habitat. There are two general approaches for valuing the commercial fishery value of coral reefs and seagrass habitat. The first approach involves calculating the annual value of the area's catch. The second approach involves calculating the value of fish produced by acre (or hectare) of the habitat. An issue with the first approach is that as a habitat declines in health, the value of the associated catch will also decline as the amount of the fish caught declines. To account for that, ERG used data from prior time periods where coral reefs were in a healthier state and catch rates were higher.

The 2006 report used data collected from the CNMI Division of Fisheries and Wildlife (DFW), which included total annual catch and the market prices for fish in Saipan, to produce a direct market valuation of commercial fishing for Saipan. The DFW data assumed that Saipan accounted for 90 percent of the total catches. In addition, the DFW data did not account for subsistence fishing, therefore a correction factor of 1.3 was used to account for subsistence fishing not accounted for in the DFW data. Thus, the direct market value for commercial fishing was calculated by multiplying the 5-year average amount of reef-related fishing (57 thousand kg) by the reported 5-year average market price for reef related fish ($5.92 per kg or $2.69 per pound), as well as the subsistence fishing correction factor (1.3) and the percentage occurring on Saipan (90 percent) to obtain a core estimate of $430,000 per year for total commercial fishery value.

ERG's approach to calculating the value of fishery is to update these values based on new data and to also account for the economic value being provided by seagrass. First, since we are no longer concerned with just Saipan, we remove the 90 percent adjustment factor. The Western Pacific Fisheries Information Network (WPacFIN) (2019) provides data on total landings; ERG used those data to calculate a weighted average price per pound of $2.57 for 2018. Table 4 provides data on the total catch of reef-related fish from 1983-2016 (WPRFMC, 2017); taking the average for the last five years results in a total catch of 41,122 pounds (18.7 kg). Applying a subsistence adjustment factor of 1.3 and multiplying by $2.57 per pound results in an estimated annual value of $137,200. This estimate is significantly smaller than the value estimated in the 2006 ($625,100). This reduced value, however, is based on a significant reduction in total catch of reef-related fish over time and a reduced price for fish.[8]

An alternative estimate for the total catch would be to use a time period where total catch was higher, potentially reflecting a healthier habitat. As can be seen in Table 4, between 1989 and 2003, total catch appeared to be significantly higher and had five-year averages that varied between 193,000 and 238,500. Taking the average of the five-year averages from 1989 to 2003 results in 219,488 pounds per year, a value five times greater than the five-year average from 2012-2016. Using the higher five-year average results in an estimated value of $732,200 per year (using $2.57 per pound). ERG used the time period with higher catch rates since the purpose of this analysis was to estimate the value of healthy

[8] Note: the price per pound for the 2006 study is in 2006 prices while the price we use in this calculation is a 2018 value.

ecosystems. Thus, further damage to coral reefs and seagrass habitats should be measured against the value of a healthy ecosystem.

**Table 4. Total Catch of Reef Fishes 1981-2015 with Five-Year Rolling Averages**

| Year | Reef Fishes | Rolling Five-Year Average |
|---|---|---|
| 1983 | 165,854 | - |
| 1984 | 212,854 | - |
| 1985 | 188,292 | - |
| 1986 | 198,720 | - |
| 1987 | 176,787 | 188,501.4 |
| 1988 | 220,751 | 199,480.8 |
| 1989 | 341,704 | 225,250.8 |
| 1990 | 254,769 | 238,546.2 |
| 1991 | 141,554 | 227,113 |
| 1992 | 183,223 | 228,400.2 |
| 1993 | 191,632 | 222,576.4 |
| 1994 | 246,520 | 203,539.6 |
| 1995 | 202,791 | 193,144 |
| 1996 | 205,948 | 206,022.8 |
| 1997 | 235,331 | 216,444.4 |
| 1998 | 256,244 | 229,366.8 |
| 1999 | 216,037 | 223,270.2 |
| 2000 | 233,969 | 229,505.8 |
| 2001 | 232,500 | 234,816.2 |
| 2002 | 210,855 | 229,921 |
| 2003 | 139,249 | 206,522 |
| 2004 | 120,466 | 187,407.8 |
| 2005 | 174,630 | 175,540 |
| 2006 | 173,630 | 163,766 |
| 2007 | 173,946 | 156,384.2 |
| 2008 | 158,572 | 160,248.8 |
| 2009 | 124,312 | 161,018 |
| 2010 | 85,127 | 143,117.4 |
| 2011 | 90,956 | 126,582.6 |
| 2012 | 50,018 | 101,797 |
| 2013 | 35,567 | 77,196 |
| 2014 | 45,942 | 61,522 |
| 2015 | 26,986 | 49,893.8 |
| 2016 | 47,097 | 41,122 |

Source: WPacFIN, 2019.

Finally, for the purposes of this assessment we distributed the total economic value between coral reefs and seagrass. The 2006 report assumed that all value was attributable to coral reefs. In contrast, ERG has assumed that the economic value must be distributed between the two habitats. We assume that the value attributable to each is proportional to the total area of each habitat. From Table 1 we can see that 94 percent of the total area is coral reef and the remaining six percent is seagrass. Thus, we attribute 94 percent to coral reefs ($688,600) and the remaining to seagrass ($43,600).

ERG was not able to spatially distribute these estimates over the areas of coral reefs and seagrass; thus, we have assumed that each hectare (or acre) contributes equally to creating the economic value that was estimated. Recommendations to provide more spatially explicit value estimates are detailed subsequently in the "next steps" section to support continued analysis of resource benefits and management implications.

**Next Steps**

ERG recommends that CNMI consider the following next steps for these estimates:

- Update the estimates in this section using new data on an annual basis. Each key data input in this section (landings, price per pound, etc.) will have new data annually. Using those new data will allow for regular updates using current numbers.
- Perform additional research on using the "high catch rate" period to estimate value. This report has provided a reasoned argument for using that time period, but we have not performed additional in-depth research into using that assumption.
- Perform research into the relative productivity of coral reefs and seagrass in terms of fisheries and adjust the distribution between the two habitats accordingly to support spatially explicit ecovaluation updates.

## 3.0 Non-Commercial Fishing

The 2006 report used a discrete choice experiment conducted on Guam as the basis for the CNMI non-market fishing valuation. The lower bound estimate was calculated by taking the Guam per household valuation and using CNMI and Guam per capita purchasing power to estimate the CNMI value per household (as income level was determined to be a factor that could explain the differences in cultural value between the Islands). The total value was then calculated by multiplying the CNMI per household value by the number of households that benefit from fishing (data taken from the household survey), resulting in an annual lower bound estimate of $208,265. The upper bound was calculated by multiplying the upper bound estimate for per household cultural value, calculated from the choice experiment, by the total number of households on Saipan, resulting in an annual upper bound estimate of $1,448,189. The core estimate was then calculated as the average of the upper and lower bounds, which was $830,000 per year.

The methodology used in the 2006 report served as a basis for the non-commercial fishing valuation for this updated valuation. The lower bound per household value was calculated from the cultural value for fishing found in Guam ($43.06 per household), which after accounting for inflation (based on U.S. CPI data) was found to be $54.04 per household (2017 USD). To adapt this value for CNMI, the 2016 per capita purchasing power parity for CNMI ($24,500) and Guam ($35,600) were used (CIA data). The per household cultural value for fisheries was then calculated by multiplying the ratio of CNMI and Guam's purchasing powers ($24,500/$35,600) by the Guam estimate ($54.04/household), which was found to be $37.19 per household.

The upper bound per household value was calculated by updating the value used in the 2006 report for inflation. The choice experiment for Guam was used to derive the upper bound for the 2006 report ($73.49 per household), which after accounting for inflation (based on U.S. CPI data) was found to be $92.24 per household (2017 USD).

To find the annual upper and lower bounds, the number of households on CNMI is needed. In 2017 the population of CNMI was 52,263 people. The 2006 report estimated that there were 3.66 persons per household on Saipan; we used this as an estimate for all of CNMI. The total number of households can then be estimated as 52,263 people divided by 3.66 people per household which results in the estimate of 14,280 households. In addition, the percentage of households benefiting from the cultural value of fisheries was adapted from the 2006 report, those values being 45% for the lower bound calculated from the household survey, which assumes only families that participate in fishing benefit from the cultural value of fisheries, and 100% for the upper bound which assumes that all households benefit from the cultural value of fisheries.

The annual lower bound for the non-market fishing value is calculated by multiplying the lower bound per household value ($37.19 by the number of households (14,280 households) and the lower bound percentage of households benefiting from the cultural value of fisheries (45%) which produces the lower bound estimate of $239,000 per year.

The annual upper bound for the non-market fishing value is calculated by multiplying the upper bound per household value ($92.24 per household) by the number of households (14,280 households) and the upper bound percentage of households benefiting from the cultural value of fisheries (100%) which produces the upper bound estimate of $1,317,100 per year.

Our preferred estimate for non-market fishing value is the average of the upper and lower bounds, which is $778,100 per year. This value applies to both coral reefs and seagrass combined; thus, we divided the value between the two habitats applying 94 percent of the value to coral reefs ($731,800) and six percent to seagrass ($46,300) (see Table 1 for percentages). Furthermore, as with the commercial fishing estimate, we were unable to distribute the estimated values over the spatial extent of the coral reef and seagrass.

**Next Steps**

ERG recommends that the next step for estimating the value of this ecosystem service would be to repeat and possibly expand the survey and associated analysis conducted for Guam for the 2006 report for CNMI. This would allow CNMI to develop a more precise and more relevant estimate for this and other ecosystem services. As with commercial fishing, BECQ-DCRM should perform research into the relative productivity of coral reefs and seagrass in terms of fisheries and adjust the distribution between the two habitats accordingly.

## 4.0 Tourism

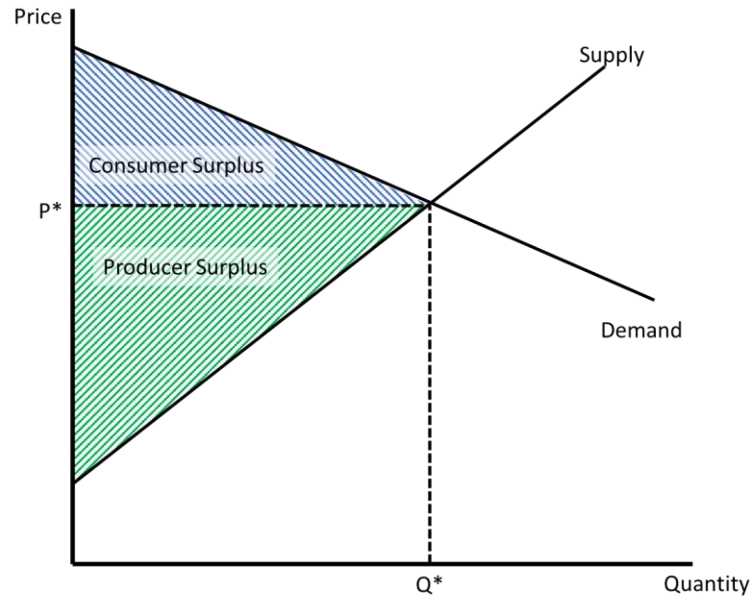



**Figure 4. Consumer and Producer Surplus in a Demand and Supply Graph**

To develop estimates for tourism, ERG divided the process into developing estimates for consumer surplus value and producer surplus values separately. In economic theory, consumer surplus reflects the value to consumers from paying a (market) price for something that is lower than the amount they are willing to pay to the item. For example, a consumer may be willing to pay $15,000 for a car, but if the market price for the car is only $5,000, then the consumer gains $10,000 in value. Similarly, producer surplus is the amount that firms earn to provide goods and services above the minimum they need to be compensated to provide that good or service. Figure 4 provides a textbook example of consumer and producer surplus in a demand and supply graph from economic theory. The area under the demand curve and above market price (P*) is considered consumer surplus and the area above the supply curve and below market price is considered producer surplus. The sum of producer and consumer surplus is considered total value for a market. Taking into account both consumer and producer surplus is important for estimating the value of tourism and recreation (next section). First, both tourism and recreation involve providing value to a consumer and measuring that value is important. Second, the suppliers of the goods and services are local residents and clearly benefit from tourism and recreation spending.

### 4.1 Foreign Tourism Producer Surplus Value

#### *4.1.1 Estimates*

The 2006 report used direct market valuation to estimate the annual tourism producer surplus for Saipan. Gross tourist expenses were calculated from tourist exit surveys. A marine-related tourism factor, which determined how much of tourism on Saipan was marine related, was also calculated from tourist exit surveys. A cost price factor that accounts for the value added of the tourist industry was adopted from a study of the Hawaiian economy. The per visitor producer surplus was then calculated by multiplying the gross tourist expenses ($1,017) by the marine related factor (29.6%) and the cost price factor (25%) which amounts to $75/visitor. The total marine related producer surplus for tourism was then calculated by multiplying the per visitor amount ($75) by the average number of visitors per year to Saipan (500,000 visitors) to obtain an annual value of $37.7 million.

For this report, producer surplus value for foreign tourism was calculated by aggregating data from the five main foreign tourism markets: Japan, Korea, China, Russia, and Guam. For each market, an analysis occurred and then the five separate market values were summed to produce the total foreign tourism producer surplus value.

Table 5 summarizes the process of estimating the value of tourism. First, we relied on the following data to find the total annual producer surplus for each market: expenditure per person (2011 value that is updated to account for inflation based on U.S CPI data), and the percentage of visitors coming to CNMI for coastal amenities. Multiplying these factors results in an estimate of $270,668,900. Next, we adjusted the estimate using a 25 percent cost price factor to reflect the idea that only the cost of providing the services should be considered. The 2006 report used this cost price factor in its analysis as well and is based on a similar analysis done for the Hawaiian economy. Multiplying these factors results in an estimate for annual foreign tourism producer surplus of $67,667,200.

For purposes of providing spatially-explicit values, we assumed that reef and seagrass areas that were closer to shoreline access points and swimming areas would provide higher values. Based on best professional judgement from local resource managers, we used the following weighting scheme:[9]

- Coral reefs and seagrass beds within 500 meters of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon were assigned a weight of 9.
- Coral reefs and seagrass beds between 500 and 1,000 meters of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon were assigned a weight of 5.
- Coral reefs and seagrass beds between 1,000 and 1,500 meters of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon were assigned a weight of 3.
- Coral reefs and seagrass beds more than 1,500 meters from dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon were assigned a weight of 1.

Table 6 provides the distribution of coral reef values by distance from shoreline access points of swim zones and Table 7 does the same for seagrass.

This approach also effectively distributes the total estimated value between coral reefs and seagrass; however, the distribution is based on distances to shoreline access and swim zones rather than on relative total areas of each. Based on this, the amount attributable to coral reefs is $60.3 million and the amount attributable to seagrass is $7.4 million.

[9] This approach is based on the 2006 report.

Table 5. Estimated Tourism-Related Expenses

| Origin Country | Expenditure per person (2011 USD) [a] | Expenditure per person (2018 USD) | Annual number of visitors (FY 2016) [a] | Percentage of visitors who come to CNMI due to coastal amenities [a] | Estimated Values | |
|---|---|---|---|---|---|---|
| | | | | | No Cost Price Factors Applied | Including Cost-Price Factor (25%) |
| Japan | $758.20 | $849.43 | 60,225 | 84% | $42,971,800 | $10,743,000 |
| Korea | $568.73 | $637.17 | 200,570 | 67% | $85,624,100 | $21,406,000 |
| China | $681.40 | $763.39 | 206,525 | 82% | $129,280,500 | $32,320,100 |
| Russia | $4,129 | 4,625.84 | 1,796 | 100% | $8,308,000 | $2,077,000 |
| Guam | $652.37 | $730.87 | 12,783 | 48% | $4,484,500 | $1,121,100 |
| **Totals** | - | - | - | - | **$270,668,900** | **$67,667,200** |

[a] MVA, 2012.

**Table 6. Distribution of Total Tourism-Related Producer Surplus Value for Coral Reefs by Distance of Coral Reefs to Shoreline Access Points and Swim Zones**

| Category | Weight | Area ($km^2$) | Weighting Score [a] | Total Value [b] | Value per $Km^2$ |
|---|---|---|---|---|---|
| Reefs within 0-500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 9 | 35.41 | 318.69 | $39,316,100 | $1,110,300 |
| Reefs within 500-1000m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 5 | 19.02 | 95.10 | $11,732,300 | $616,800 |
| Reefs within 1000-1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 3 | 11.88 | 35.64 | $4,396,800 | $370,100 |
| Reefs beyond 1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 1 | 39.04 | 39.04 | $4,816,300 | $123,400 |

[a] Calculated by multiplying the weighting value by the area.

[b] Calculated by multiplying the total value estimated in this section by the weighting score as a percentage of all weighting scores across both coral reefs and seagrass.

**Table 7. Distribution of Total Tourism-Related Producer Surplus Value for Seagrass by Distance of Seagrass to Shoreline Access Points and Swim Zones**

| Category | Weight | Area ($km^2$) | Weighting Score [a] | Total Value [b] | Value per $Km^2$ |
|---|---|---|---|---|---|
| Seagrass within 0-500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 9 | 6.67 | 60.03 | $7,405,800 | $1,110,300 |
| Seagrass within 500-1000m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 5 | 0 | 0.00 | $0 | $0 |
| Seagrass within of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 3 | 0 | 0.00 | $0 | $0 |

| Category | Weight | Area ($km^2$) | Weighting Score [a] | Total Value [b] | Value per $Km^2$ |
|---|---|---|---|---|---|
| Seagrass beyond 1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 1 | 0 | 0.00 | $0 | $0 |

[a] Calculated by multiplying the weighting value by the area.

[b] Calculated by multiplying the total value estimated in this section by the weighting score as a percentage of all weighting scores across both coral reefs and seagrass.

### 4.1.2 Maps

ERG also developed a set of maps reflecting the distribution of coral reefs and seagrass from shoreline access points and swim zones that mirror the categories we used to distribute the values in Table 6 and Table 7. The coral reef maps appear in Figure 5 (Saipan), Figure 6 (Rota), and Figure 7 (Tinian) and the seagrass map for Saipan appears in Figure 8.

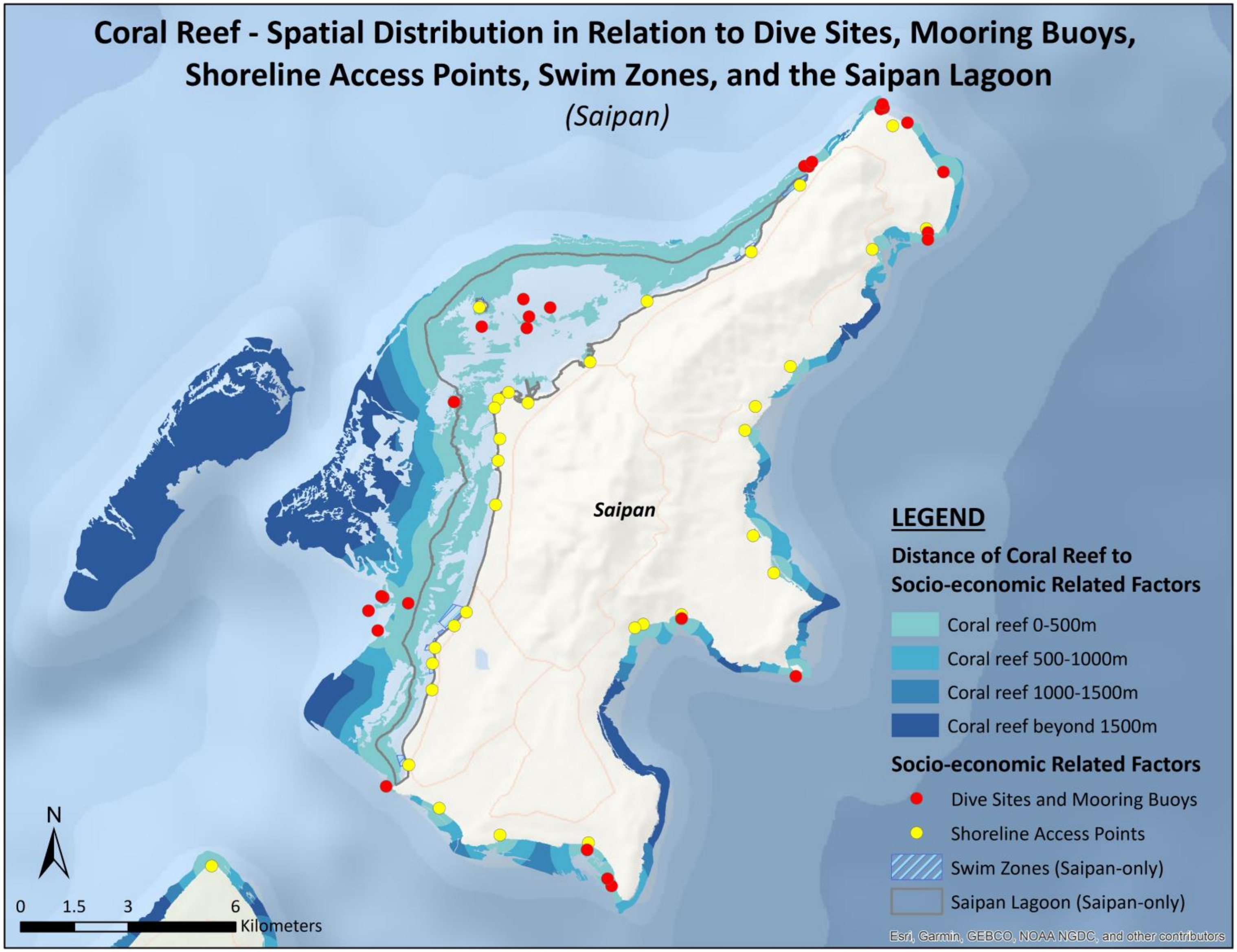



**Figure 5. Distribution of Coral Reefs in Relation to Dive Sites, Mooring Buoys, Shoreline Access Points, Swim Zones, and the Saipan Lagoon, Saipan**

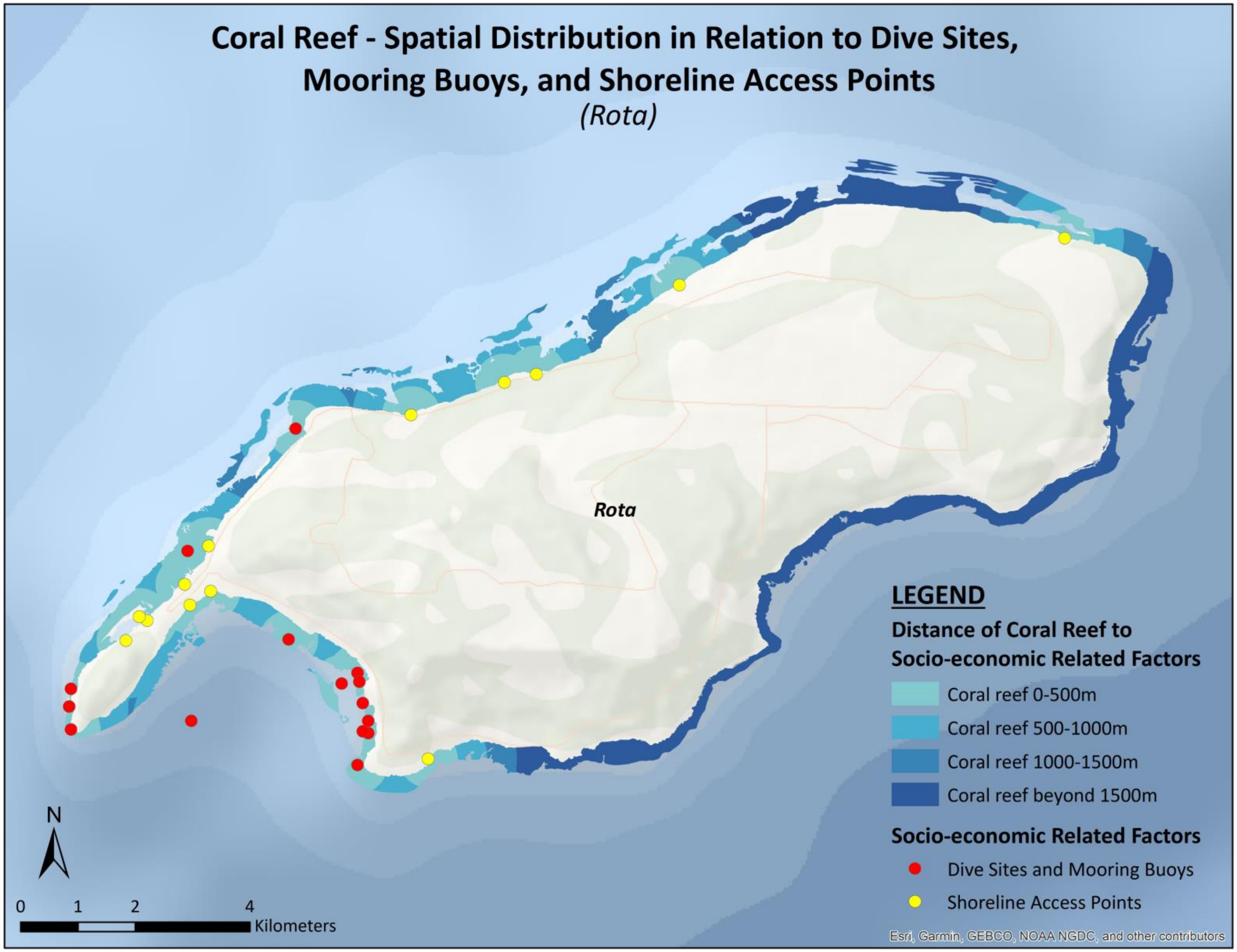



**Figure 6. Distribution of Coral Reefs in Relation to Dive Sites, Mooring Buoys, and Shoreline Access Points, Rota**

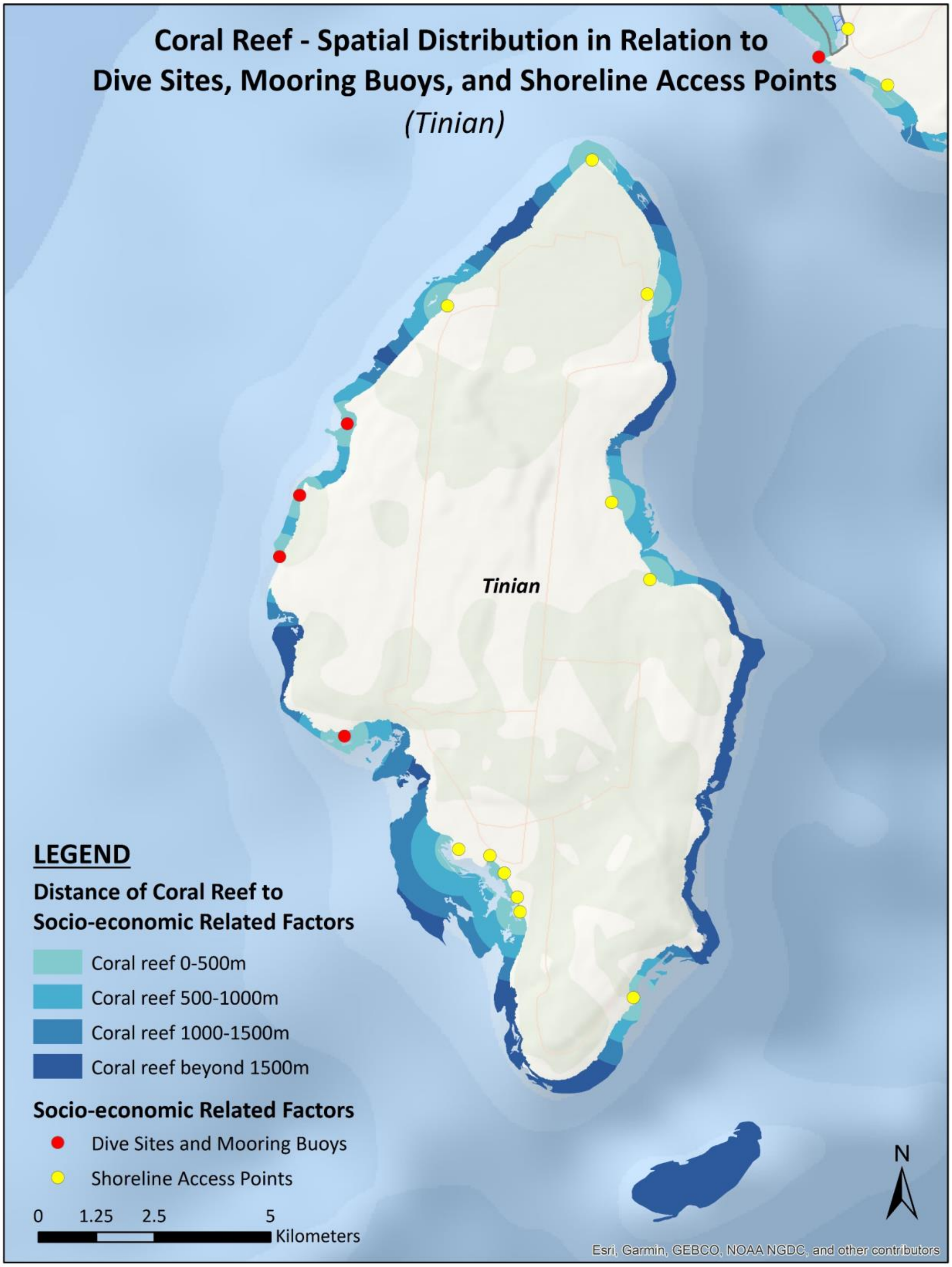



**Figure 7. Distribution of Coral Reefs in Relation to Dive Sites, Mooring Buoys, and Shoreline Access Points, Tinian**

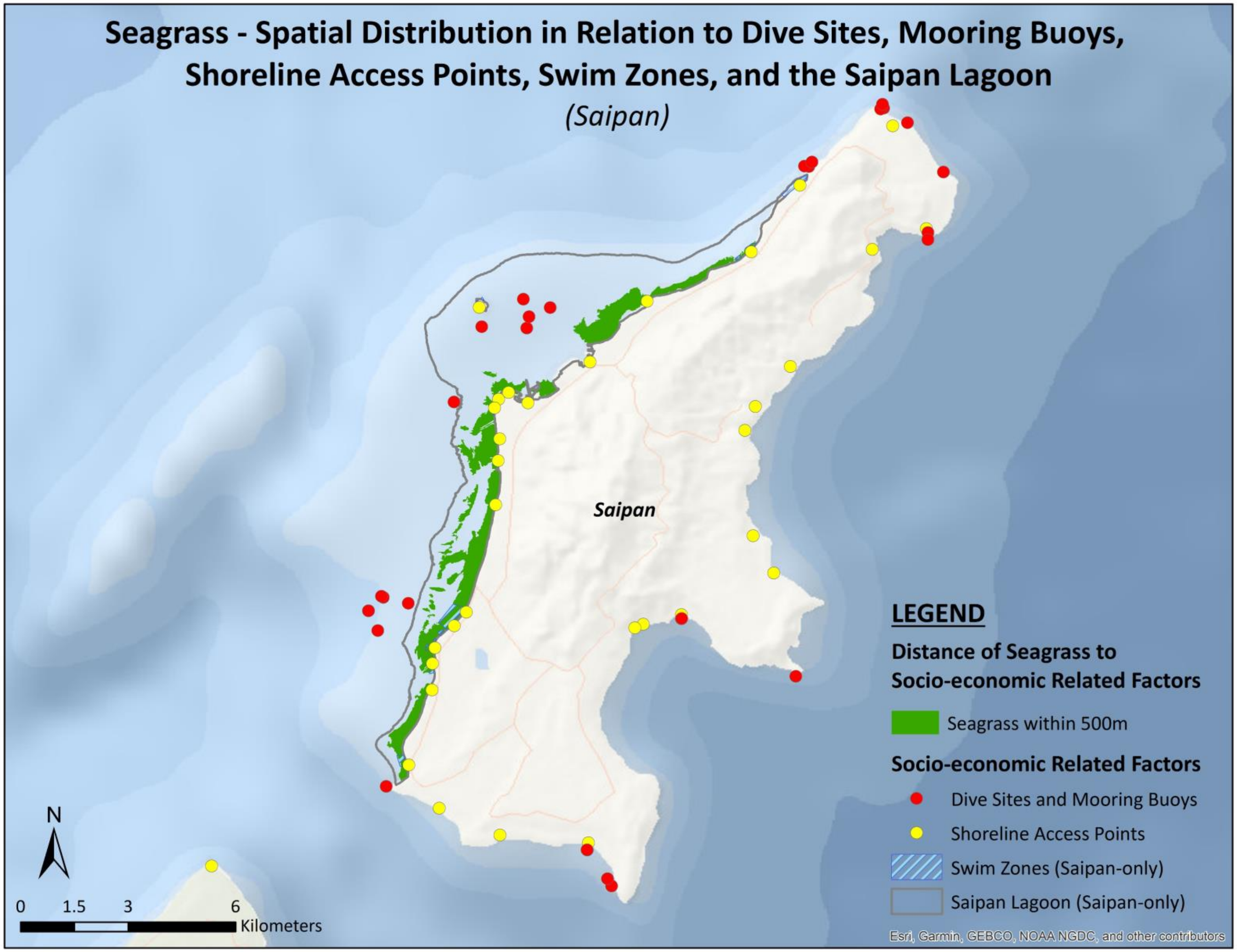



**Figure 8. Distribution of Seagrass in Relation to Dive Sites, Mooring Buoys, Shoreline Access Points, Swim Zones, and the Saipan Lagoon, Saipan**

## 4.2 Foreign Tourism Consumer Surplus Value

### *4.2.1 Estimates*

The 2006 report used a benefit transfer method based on a meta-analysis of contingent valuation methods (CVM) studies to derive an annual estimate for tourism consumer surplus. A meta-analysis of coral-reef related studies was conducted to derive a proxy for WTP for tourism on Saipan. A database developed by Brander and Van Beukering was used to extract estimates from 47 studies containing CVM estimates for WTP for recreational use of coral reefs. The average of these estimates was found to be a WTP of $9.23 per person per trip. The core estimate was then derived by multiplying the average WTP from the meta-analysis ($9.23/person/trip) by the average number of visitors to Saipan each year (500,000 visitors) to obtain an annual estimate of $4.61 million.

The 2006 report was used as a basis for the foreign tourism consumer surplus value. The 2006 report used a meta-analysis to find an average consumer WTP, which was reported as $9.23 per person per trip, which after updating to account for inflation (based on U.S. CPI data) was found to be $11.91 (2018 USD). The number of visitors to CNMI in 2016 was 501,489 visitors (MVA, 2016). Multiplying these two values produces the foreign tourism consumer surplus value of $5,972,700 per year.

Table 8 and Table 9 provide a distribution of the estimated values across distances to shoreline access points and swim zones. These estimates were made based on the approach described in the last section. Additionally, these estimates also distribute the total estimated value between coral reefs and seagrass with a total of $5,319,100 being attributed to coral reefs and $653,600 being attributed to seagrass.

**Table 8. Distribution of Total Tourism-Related Consumer Surplus Value for Coral Reefs by Distance of Coral Reefs to Shoreline Access Points and Swim Zones**

| Category | Weight | Area (km$^2$) | Weighting Score [a] | Total Value [b] | Value per Km$^2$ |
|---|---|---|---|---|---|
| Reefs within 0-500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 9 | 35.41 | 318.73 | $3,470,600 | $98,000 |
| Reefs within 500-1000m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 5 | 19.02 | 95.08 | $1,035,300 | $54,400 |
| Reefs within 1000-1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 3 | 11.88 | 35.64 | $388,100 | $32,700 |
| Reefs beyond 1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 1 | 39.04 | 39.04 | $425,100 | $10,900 |

[a] Calculated by multiplying the weighting value by the area.

[b] Calculated by multiplying the total value estimated in this section by the weighting score as a percentage of all weighting scores across both coral reefs and seagrass.

**Table 9. Distribution of Total Tourism-Related Consumer Surplus Value for Seagrass by Distance of Seagrass to Shoreline Access Points and Swim Zones**

| Category | Weight | Area (km$^2$) | Weighting Score [a] | Total Value [b] | Value per Km$^2$ |
|---|---|---|---|---|---|
| Seagrass within 0-500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 9 | 6.67 | 60.03 | $653,600 | $98,000 |
| Seagrass within 500-1000m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 5 | 0.00 | 0.00 | $0 | $0 |
| Seagrass within of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 3 | 0.00 | 0.00 | $0 | $0 |
| Seagrass beyond 1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 1 | 0.00 | 0.00 | $0 | $0 |

[a] Calculated by multiplying the weighting value by the area.

[b] Calculated by multiplying the total value estimated in this section by the weighting score as a percentage of all weighting scores across both coral reefs and seagrass.

### 4.2.2 Maps

Given that we used the same distances for this estimate as we did for producer surplus, the maps that appear in Section 4.1.2. The coral reef distributions from shoreline access points and swim zones can be found in Figure 5 (Saipan), Figure 6 (Rota), and Figure 7 (Tinian) and the same distributions for seagrass for Saipan can be found in Figure 8.

## 4.3 Next Steps

In order to keep these estimates up to date, CNMI should continue to update the values for the dollars spent per person from different countries and the number of annual trips taken by visitors from those countries. Additionally, CNMI should spend additional time and effort to identify the places that tourists visit that are related to coastal habitats. CNMI should determine which locations are most popular to allow for better spatial distribution of the estimates. This information could be gathered using site-specific survey methods or incorporated into exit survey data collection efforts currently being implemented by the Marianas Visitors Authority.

# 5.0 Recreation

The 2006 report used a direct market valuation to estimate the annual recreation producer surplus for Saipan. Gross recreation expenses, number of people participating in each activity, and number of trips per person values were calculated from tourist exit surveys. Annual values for each recreational activity were calculated by multiplying the gross expense (ranging from $30-$70 per trip) by a cost price factor of 40% and the total number of trips (which ranged from 15,000 to 200,000 depending on the activity). Then the annual value of each activity was summed to obtain the annual total recreation producer surplus of $5.77 million.

## 5.1 Producer Surplus

ERG followed a process similar to the one used in the 2006 study and in our estimate of foreign tourism producer surplus. For recreation, however, the estimates are based on numbers of activities for three specific activities and rather than for the origin of the consumers. Specifically, we focused on three activities that were also covered by the 2006 report: diving, snorkeling, and underwater observation. Table 10 provides our calculation of producer surplus. The total number of activities and the value per activity were calculated from an informal survey that CNMI conducted of diving, snorkeling, and underwater observation operations on Saipan. In the survey, CNMI staff contacted 75 operations and asked about the average monthly number of activities for each activity and the typical cost for each. Multiplying the total number of annual activities by the value per activity provides an initial estimate of the total economic value. However, as with the foreign tourism estimate, we multiply by a cost-price factor of 25% to reflect the value-added associated with the activity. This results in a total annual estimate of $1.5 million for recreation producer surplus. This estimate is then distributed spatially in Table 11 (coral reefs) and Table 12 (seagrass); we estimated that $1.3 million was attributable to coral reefs and $162,000 was attributable to seagrass.

**Table 10. Calculation of Recreation-Related Producer Surplus**

| Activity | Total Number of Annual Activities [a] | Value per Activity [a] | Cost-Price Factor | Total Value |
|---|---|---|---|---|
| Diving | 40,044 | $45.00 | 25% | $450,495 |
| Snorkeling | 124,992 | $25.50 | | $796,824 |
| Underwater Observation | 19,080 | $48.75 | | $232,538 |
| **Totals** | - | - | - | **$1,479,857** |

[a] The data on the number of annual activities and the cost per activity were collected from an informal survey of 75 diving, snorkeling, and underwater observation operators on Saipan.

**Table 11. Distribution of Total Recreation-Related Producer Surplus Value for Coral Reefs by Distance of Coral Reefs to Shoreline Access Points and Swim Zones**

| Category | Weight | Area (km$^2$) | Weighting Score [a] | Total Value [b] | Value per Km$^2$ |
|---|---|---|---|---|---|
| Reefs within 0-500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 9 | 35.41 | 318.69 | $859,800 | $24,300 |
| Reefs within 500-1000m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 5 | 19.02 | 95.10 | $256,600 | $13,500 |
| Reefs within 1000-1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 3 | 11.88 | 35.64 | $96,200 | $8,100 |
| Reefs beyond 1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 1 | 39.04 | 39.04 | $105,300 | $2,700 |

[a] Calculated by multiplying the weighting value by the area.

[b] Calculated by multiplying the total value estimated in this section by the weighting score as a percentage of all weighting scores across both coral reefs and seagrass.

**Table 12. Distribution of Total Recreation-Related Producer Surplus Value for Seagrass by Distance of Seagrass to Shoreline Access Points and Swim Zones**

| Category | Weight | Area (km$^2$) | Weighting Score [a] | Total Value [b] | Value per Km$^2$ |
|---|---|---|---|---|---|
| Seagrass within 0-500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 9 | 6.67 | 60.03 | $162,000 | $24,300 |
| Seagrass within 500-1000m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 5 | 0.00 | 0 | $0 | $0 |
| Seagrass within of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 3 | 0.00 | 0 | $0 | $0 |
| Seagrass beyond 1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 1 | 0.00 | 0 | $0 | $0 |

[a] Calculated by multiplying the weighting value by the area.

[b] Calculated by multiplying the total value estimated in this section by the weighting score as a percentage of all weighting scores across both coral reefs and seagrass.

## 5.2 Consumer Surplus

Estimating the consumer surplus associated with recreation activities follows a similar approach as the producer surplus estimate: we multiply the number of activities by the value (to consumers) of those activities. A cost-price factor adjustment is not needed. The value of the activities will also reflect the consumer willingness to pay for those activities.

To determine the willingness to pay (WTP) for each activity, ERG performed background research into relevant studies for each activity. ERG was unable to find relevant studies that distinguished "diving" from "snorkeling." ERG was also unable to identify any studies that were specific to "underwater observation." A study by Grafeld et al. (2016) provides estimates of divers' willingness to pay for improved coral reef conditions in Guam. ERG calculated an estimated per-dive WTP from that study as the WTP for diving; this estimate was $75.77 per dive in 2016 dollars in Guam;[10] we used to CPI calculator to update this value to be $79.56 in 2018 dollars. We did not adjust the Guam estimate for purchasing power parity since CNMI has less availability for diving and reportedly better dive sites. Although the estimate was developed for diving, we applied the value to both snorkeling and underwater observation as well given than we had not better data to use to calculate WTP for those activities. To account for the cost paid by consumers, we subtracted the amount paid per activity (see Table 10) from $49.93; these values appear in Table 13. Our estimate for consumer surplus for recreational activities is $3.7 million annually. This estimate is then distributed spatially in Table 14 (coral reefs) and Table 15 (seagrass); we estimated that $3.3 million was attributable to coral reefs and $402,900 was attributable to seagrass.

**Table 13. Calculation of Recreation-Related Consumer Surplus**

| Activity | Total Number of Annual Activities [a] | Net WTP per activity [b] | Total Value |
|---|---|---|---|
| Diving | 40,044 | $34.56 | $1,383,800.00 |
| Snorkeling | 124,992 | $54.06 | $6,756,500.00 |
| Underwater Observation | 19,080 | $30.81 | $587,800.00 |
| **Totals** | | | $8,728,100.00 |

[a] The data on the number of annual activities and the cost per activity were collected from an informal survey of 75 diving, snorkeling, and underwater observation operators on Saipan.
[b] Calculated from data taken from Grafeld et al. (2016) and adjusted for relative purchasing power between Guam and CNMI and the subtracting the cost per activity from Table 10.

[10] Grafeld et al. (2016) calculates the value of individual dive characteristics using a choice experiment framework; the dive characteristics included amount of fish biomass, diversity of fish, number of wrasse, size of wrasse, and presence of turtles and/or sharks. ERG calculated a per-dive WTP value using the log sum method which calculates the value of a set of characteristics by calculating WTP for that set compared to an alternative. We calculated the value of the having the "most preferred" set of characteristics (high biomass, high fish diversity, many wrasse, medium wrasse, and seeing both a shark and turtle) and compared that to not taking the dive at all (i.e., no characteristics of a dive are experienced). The log-sum method is standard approach to calculating a WTP value for a set of characteristics in a choice experiment.

**Table 14. Distribution of Total Recreation-Related Consumer Surplus Value for Coral Reefs by Distance of Coral Reefs to Shoreline Access Points and Swim Zones**

| Category | Weight | Area (km$^2$) | Weighting Score [a] | Total Value [b] | Value per Km$^2$ |
|---|---|---|---|---|---|
| Reefs within 0-500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 9 | 35.41 | 318.69 | $2,138,700 | $60,400 |
| Reefs within 500-1000m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 5 | 19.02 | 95.10 | $638,200 | $33,600 |
| Reefs within 1000-1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 3 | 11.88 | 35.64 | $239,200 | $20,100 |
| Reefs beyond 1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 1 | 39.04 | 39.04 | $262,000 | $6,700 |

[a] Calculated by multiplying the weighting value by the area.

[b] Calculated by multiplying the total value estimated in this section by the weighting score as a percentage of all weighting scores across both coral reefs and seagrass.

**Table 15. Distribution of Total Recreation-Related Consumer Surplus Value for Seagrass by Distance of Seagrass to Shoreline Access Points and Swim Zones**

| Category | Weight | Area (km$^2$) | Weighting Score [a] | Total Value [b] | Value per Km$^2$ |
|---|---|---|---|---|---|
| Seagrass within 0-500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 9 | 6.67 | 60.03 | $402,900 | $60,400 |
| Seagrass within 500-1000m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 5 | 0.00 | 0 | $0 | $0 |
| Seagrass within of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 3 | 0.00 | 0 | $0 | $0 |
| Seagrass beyond 1500m of dive sites, mooring buoys, shoreline access points, swim zones, and the Saipan Lagoon | 1 | 0.00 | 0 | $0 | $0 |

[a] Calculated by multiplying the weighting value by the area.

[b] Calculated by multiplying the total value estimated in this section by the weighting score as a percentage of all weighting scores across both coral reefs and seagrass.

## 5.3 Maps for Recreation-Related Producer and Consumer Surplus

The maps that show the distribution of value for recreation producer and consumer surplus can be found in Figure 9, Figure 10, and Figure 11.

## 5.4 Next Steps

In order to keep these estimates current and improve on them in the future, BECQ-DCRM should:

- Update the costs per activity and the numbers of activities on a regular basis. As discussed with DCRM, data collection regarding average number of commercial tours and price charged could be gathered during the annual permit review process, and recreational dive and snorkel information could be obtained at popular shoreline access sites, perhaps in conjunction with existing or planned user surveys in order to expand the recreational use data set.
- Map the locations where the activities occur based on input from businesses that perform these activities; this would allow for better spatial distribution of the estimates. One approach could be to use participatory GIS methods with the businesses to allow them to identify activity locations and frequencies of activities at those locations. Geospatial data should be regularly updated as mooring buoys are added and as permitted uses continue to expand to capture use areas and support expanded spatial analysis in the future.
- Perform a WTP study to estimate the value that people place on these specific activities. The study used here is based on Guam. Using a choice experiment approach would allow for placing values on the activity based on conditions that are seen in different areas (e.g., presence or abundance of certain specie) and hence more fine-tuned estimates of WTP and spatially explicit values for identified dive sites in Saipan, Tinian, and Rota.

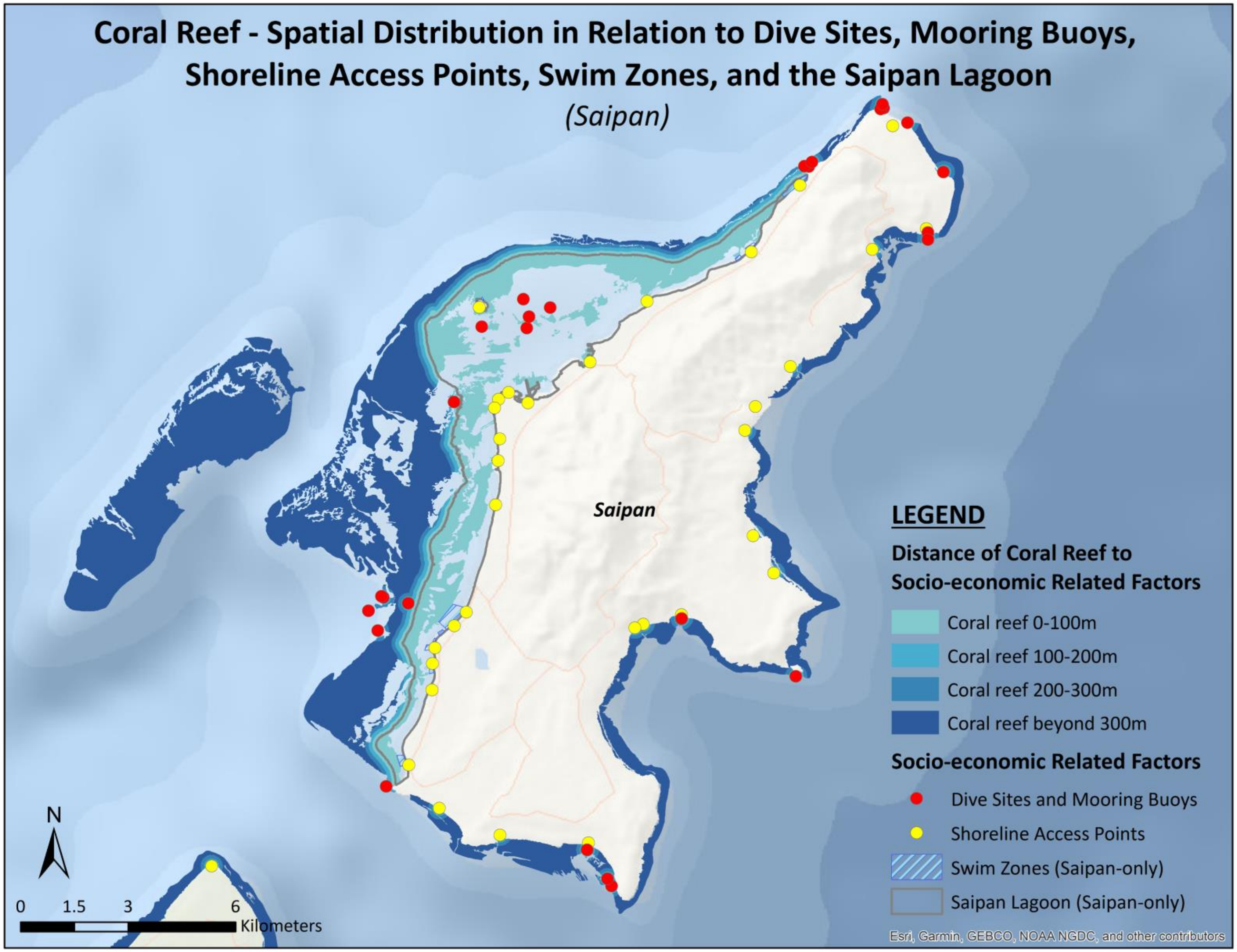



Figure 9. Distribution of Coral Reefs in Relation to Dive Sites, Mooring Buoys, Shoreline Access Points, Swim Zones, and the Saipan Lagoon, Saipan

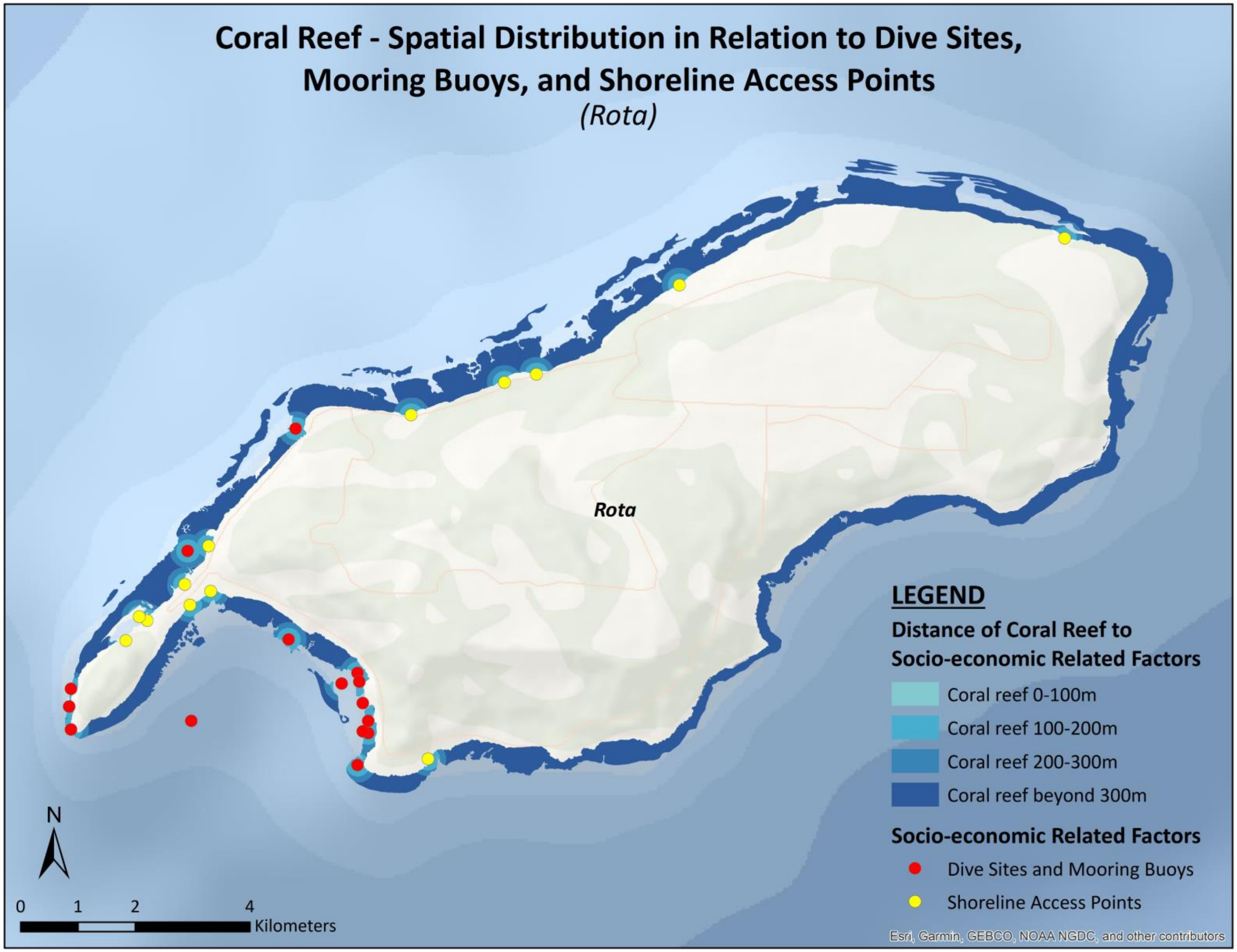



**Figure 10. Distribution of Coral Reefs in Relation to Dive Sites, Mooring Buoys, and Shoreline Access Points, Rota**

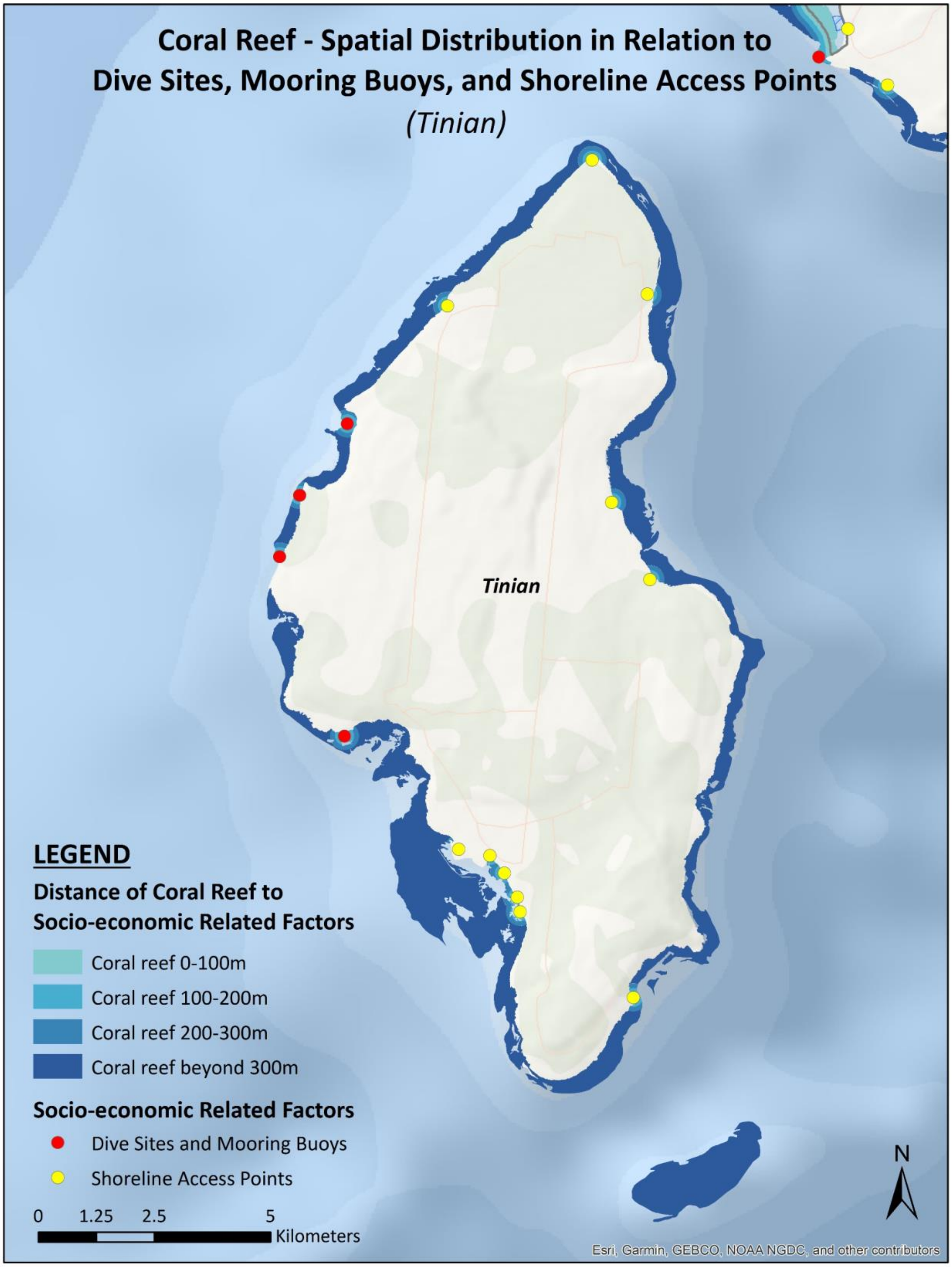



**Figure 11. Distribution of Coral Reefs in Relation to Dive Sites, Mooring Buoys, and Shoreline Access Points, Tinian**

## 6.0 Amenity-Based Property Values

Habitats such as coral reefs and seagrass improve water quality and clarity in near-shore areas. Thus, living near those habitats tends to increase property values. The 2006 report used a hedonic pricing method to calculate the amenity/property value for Saipan. A few values were used to calculate the surplus amenity values. A Guam study that was used for the Saipan study found a value function that stated that the value of a house declined by $17,000 for each km farther away from the coast. The 2000 census also reported a median house value of $159,839 for Saipan. The Saipan coast was divided into four regions, with each region farther away from the coast. Information on class 1 buildings and the total number of buildings in Saipan, reported by the Census, was used to extrapolate the number of properties residing in each of the four parcels on Saipan. This information was used to calculate a gross value for each parcel, and a surplus value per house that decreased linearly as the properties moved farther away from the coast. The number of buildings in each parcel and the surplus value per house for each parcel were multiplied to obtain a total gross surplus value for houses on Saipan. This amount ($84 million) over a time horizon of 100 years and a discount rate of 3% was found to be $4 million per year, which was an upper bound. The core estimate was found to be $3 million per year.

ERG determined that the 2006 report provided a viable approach and decided to repeat the estimates by using updated data. First, we note that property values in CNMI have declined significantly since the 2006 report was completed. According to the 2016 CNMI Household income and expenditure survey report, median home values in CNMI declined from $130,718 to $68,943 in inflation-adjusted 2016 dollars, an almost 60 percent decline in values (Central Statistics Division, 2017). Thus, we took the 2006 surplus value for the three distance ranges from the shore and adjusted those based on the decline in property values; thus, each value was reduced by approximately 57 percent. We also used the percentage of all buildings within specific distances from the shore from the 2006 report. Based on Census data, there were 20,850 residences in CNMI in 2010 (last date these data are available from the Census Bureau) (Census Bureau, 2019). We used that total to calculate the percentage of homes within each distance from the shore (see Table 16) and then calculated the total surplus value. This results in an estimated $45 million in surplus value. The 2006 report amortized the annual value over 100 years using a five percent discount rate; ERG, on the other hand, recommends a 15-year time frame and the same five percent discount rate resulting in an annual value of $5.8 million (not in Table 16).

Table 17 and Table 18 distribute to $5.8 million estimate over the distance that parcels are from coral reefs (Table 17) and seagrass (Table 18). The process also distributes the estimate between coral reefs and seagrass with approximately $4.9 million being attributed to coral reefs and $0.9 million being attributed to seagrass.

Table 16. Estimate of Amenity Value

| Distance from Shoreline | Surplus Value from 2006 Report [a] | Surplus Value Adjusted for Decline in Property Values | Percent of Properties Within Shoreline Distance [a] | Number of Properties Within Shoreline Distance | Total Surplus Value |
|---|---|---|---|---|---|
| 0 - 100m from shoreline | $25,500 | $11,000 | 5% | 1,043 | $11,473,000 |
| 100m - 250m from shoreline | $22,525 | $9,700 | 12% | 2,502 | $24,269,400 |
| 250m - 1,000m from shoreline | $14,875 | $6,400 | 7% | 1,460 | $9,344,000 |
| **Total** | **-** | **-** | **-** | **-** | **$45,086,400** |

[a] Taken from 2006 report.

Table 17. Distribution of Amenity Value for Coral Reefs Across Distance Between Coral Reefs and Parcels

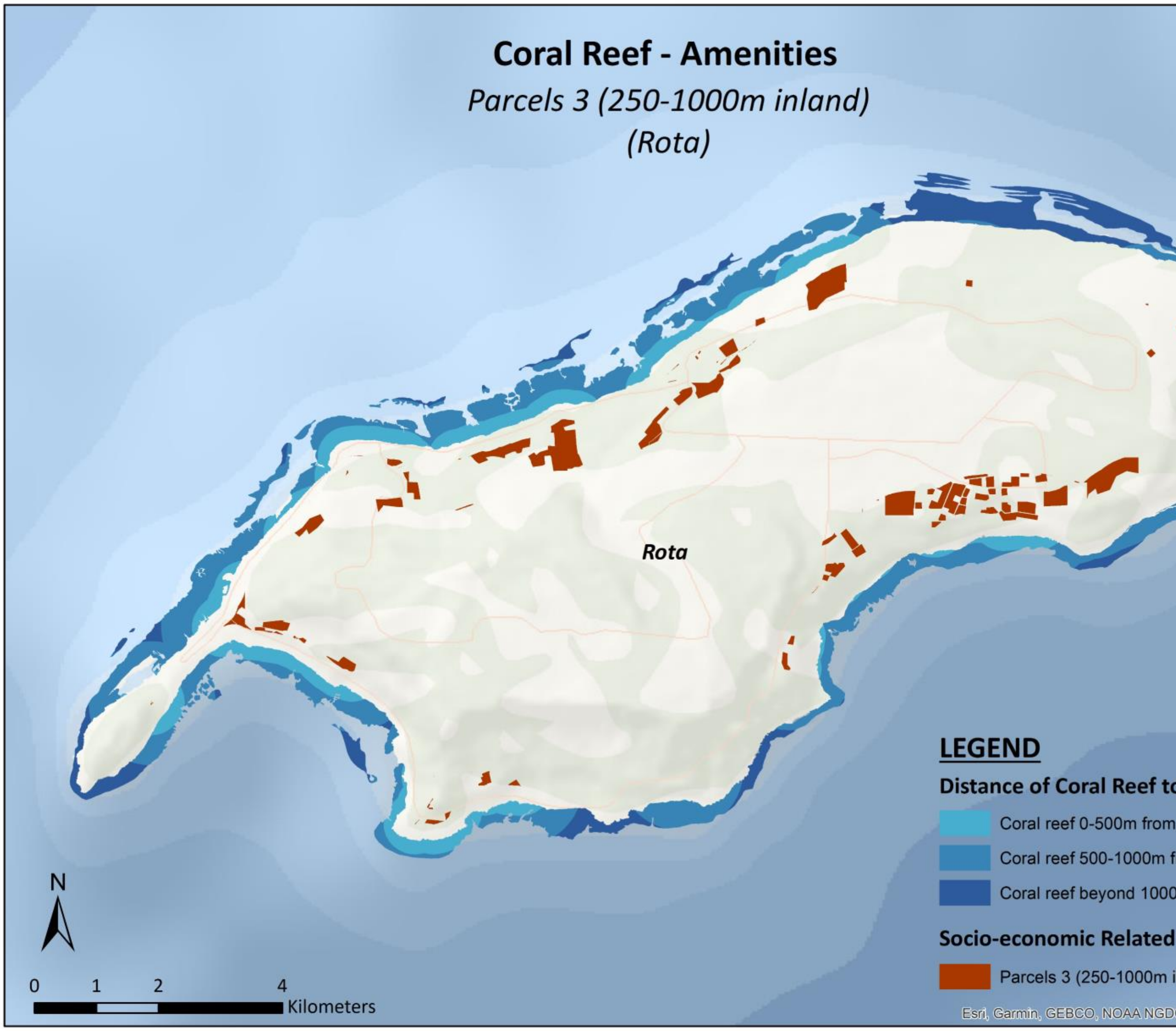
| Category | Sub-category | Weight | Area (km$^2$) | Weighted Score | Annualized Value | Annual value per km$^2$ |
|---|---|---|---|---|---|---|
| Reef layer 1 (Parcels 1) | 0-500m from parcels | 7 | 13.28 | 92.93 | $820,479 | $61,806 |
| | 500-1000m from parcels | 2 | 12.88 | 25.76 | $227,419 | $17,659 |
| | Beyond 1,000 meters | 1 | 79.20 | 79.20 | $699,246 | $8,829 |
| Reef layer 2 (Parcels 2) | 0-500m from parcels | 7 | 11.54 | 80.81 | $713,498 | $61,806 |
| | 500-1000m from parcels | 2 | 15.37 | 30.75 | $271,476 | $17,659 |
| | Beyond 1,000 meters | 1 | 78.43 | 78.43 | $692,500 | $8,829 |
| Reef layer 3 (Parcels 3) | 0-500m from parcels | 7 | 6.67 | 46.69 | $412,251 | $61,806 |
| | 500-1000m from parcels | 2 | 21.17 | 42.35 | $373,911 | $17,659 |
| | Beyond 1,000 meters | 1 | 79.44 | 79.44 | $701,447 | $8,829 |
| **0 – 500m from Parcels** | | - | **30.99** | **31.49** | **$1,946,229** | **$61,806** |
| **500 – 1000m from Parcels** | | - | **47.33** | **49.43** | **$872,807** | **$17,659** |
| **Beyond 1,000 meters** | | | | **237.07** | **$2,093,193** | **$8,829** |
| **Total for Coral Reefs** | | - | **78.32** | **317.99** | **$4,912,228** | **$15,448** |

Table 18. Distribution of Amenity Value for Seagrass Across Distance Between Seagrass and Parcels

| Category | Sub-category | Weight | Area ($km^2$) | Weighted Score | Annualized Value | Annual value per $km^2$ |
|---|---|---|---|---|---|---|
| Seagrass layer 1 (Parcels 1) | 0-500m from parcels | 7 | 5.06 | 35.40 | $312,576 | $61,806 |
| | 500-1000m from parcels | 2 | 1.47 | 2.95 | $26,042 | $17,659 |
| | Beyond 1,000 meters | 1 | 0.14 | 0.14 | $1,216 | $8,829 |
| Seagrass layer 2 (Parcels 2) | 0-500m from parcels | 7 | 4.73 | 33.14 | $292,576 | $61,806 |
| | 500-1000m from parcels | 2 | 1.70 | 3.41 | $30,105 | $17,659 |
| | Beyond 1,000 meters | 1 | 0.23 | 0.23 | $2,042 | $8,829 |
| Seagrass layer 3 (Parcels 3) | 0-500m from parcels | 7 | 3.29 | 23.05 | $203,501 | $61,806 |
| | 500-1000m from parcels | 2 | 3.02 | 6.03 | $53,265 | $17,659 |
| | Beyond 1,000 meters | 1 | 0.61 | 0.61 | $5,348 | $8,829 |
| **0 – 500m from Parcels** | | - | **9.55** | **13.08** | **$808,653** | **$61,806** |
| **500 – 1000m from Parcels** | | - | **5.72** | **6.20** | **$109,412** | **$17,659** |
| | | | | **0.97** | **$8,606** | **$8,829** |
| **Total for Seagrass** | | - | **15.26** | **20.25** | **$926,672** | **$45,752** |

The distributions of coral reefs and seagrass in relation to the parcels are presented in a series of 12 maps below broken out by the distance of parcels inland:

- The estimates for coral reefs around Saipan are presented in Figure 12 (parcels 0 – 100 meters inland), Figure 13 (100 – 250 meters inland), and Figure 14 (250 – 1,000 meters inland).
- The estimates for coral reefs around Rota are presented in Figure 15 (0 – 100 meters inland),
- Figure 16 (100 – 250 meters inland), and




- 
- Figure 17 (250 – 1,000 meters inland).
- The estimates for coral reefs around Tinian are presented in Figure 18 (0 – 100 meters inland), Figure 19 (100 – 250 meters inland), and Figure 20 (250 – 1,000 meters inland).
- The estimates for seagrass around Saipan are presented in Figure 21 (0 – 100 meters inland), Figure 22 (100 – 250 meters inland), and Figure 23 (250 – 1,000 meters inland).

**Next Steps**

ERG recommends that BECQ-DCRM perform a hedonic property valuation analysis to develop estimates of how property values vary with proximity to coral reefs and seagrass (or, alternatively, proximity to the shoreline). This would replace the study used as a basis for the estimate here and provide estimates that are based on CNMI.

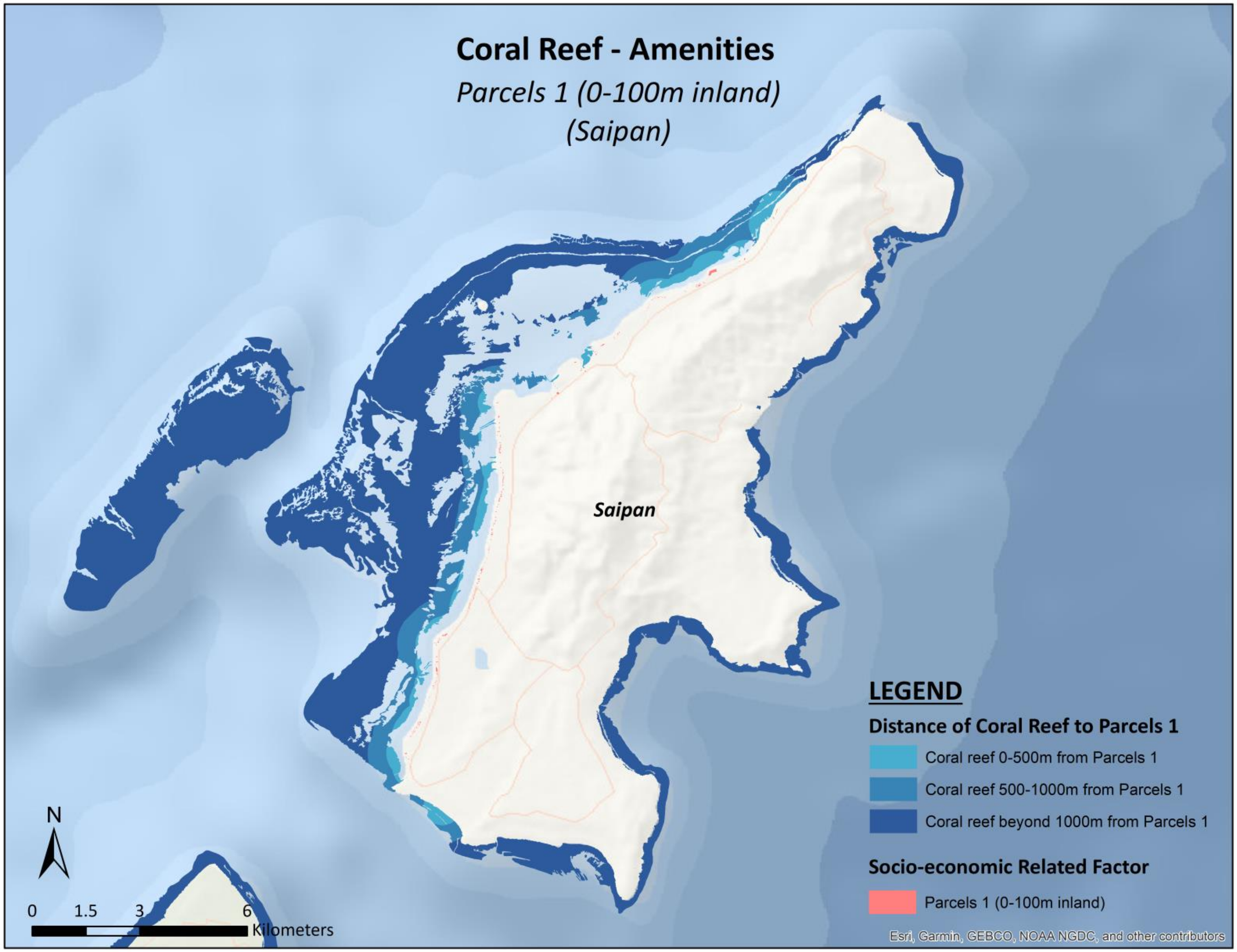



**Figure 12. Distribution of Coral Reefs in Relation to Parcels 0-100 Meters Inland, Saipan**

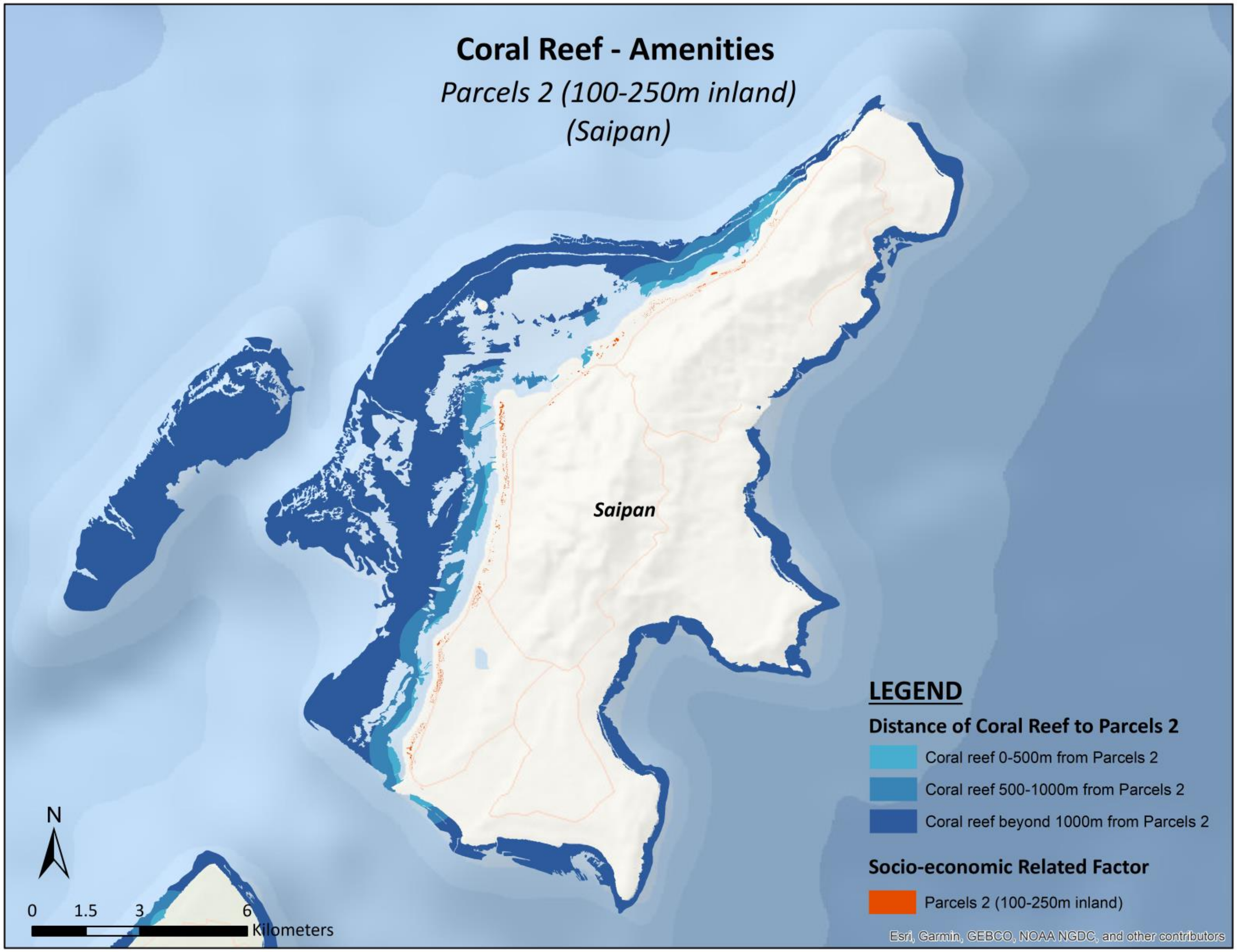



**Figure 13. Distribution of Coral Reefs in Relation to Parcels 100-250 Meters Inland, Saipan**

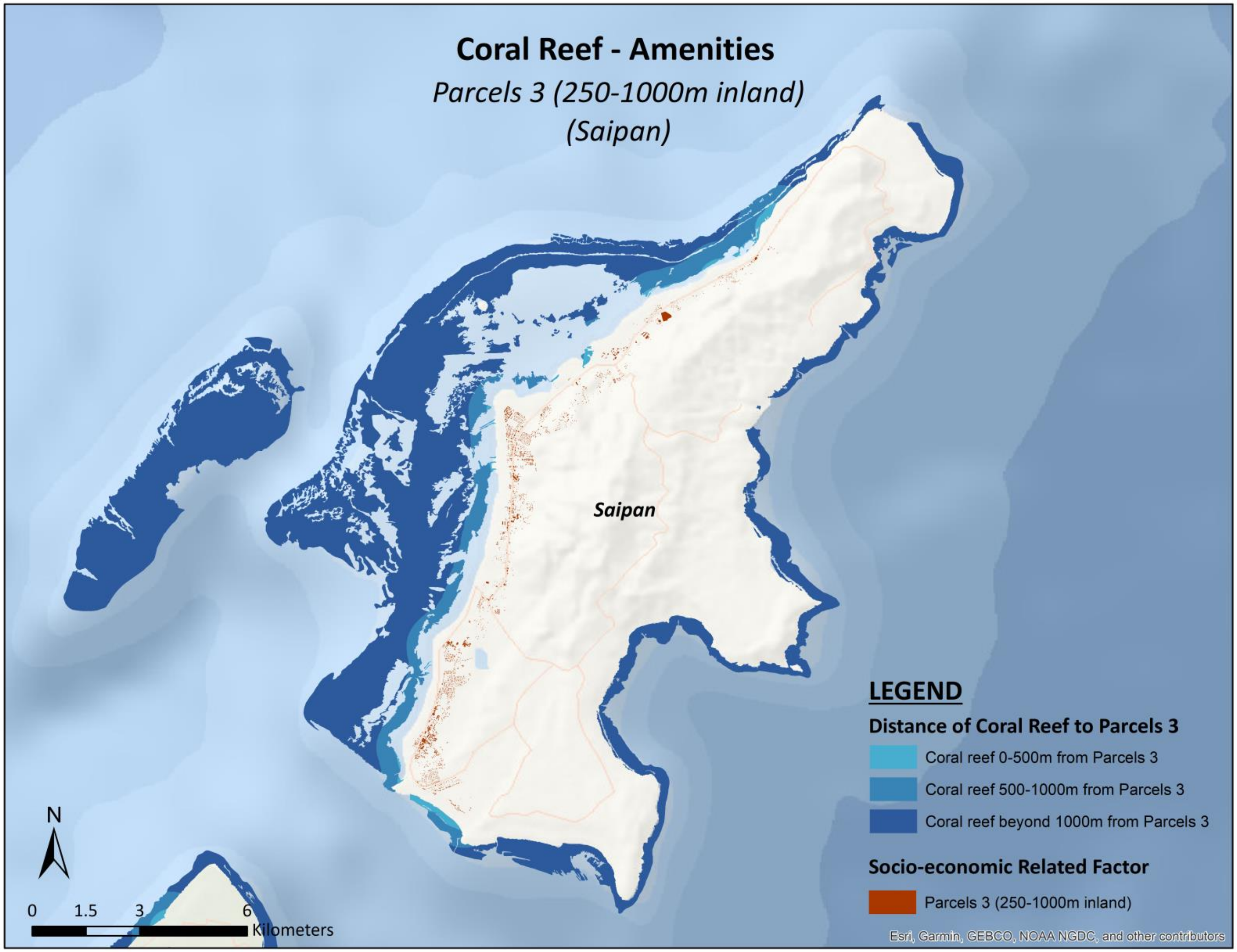



Figure 14. Distribution of Coral Reefs in Relation to Parcels 250-1000 Meters Inland, Saipan

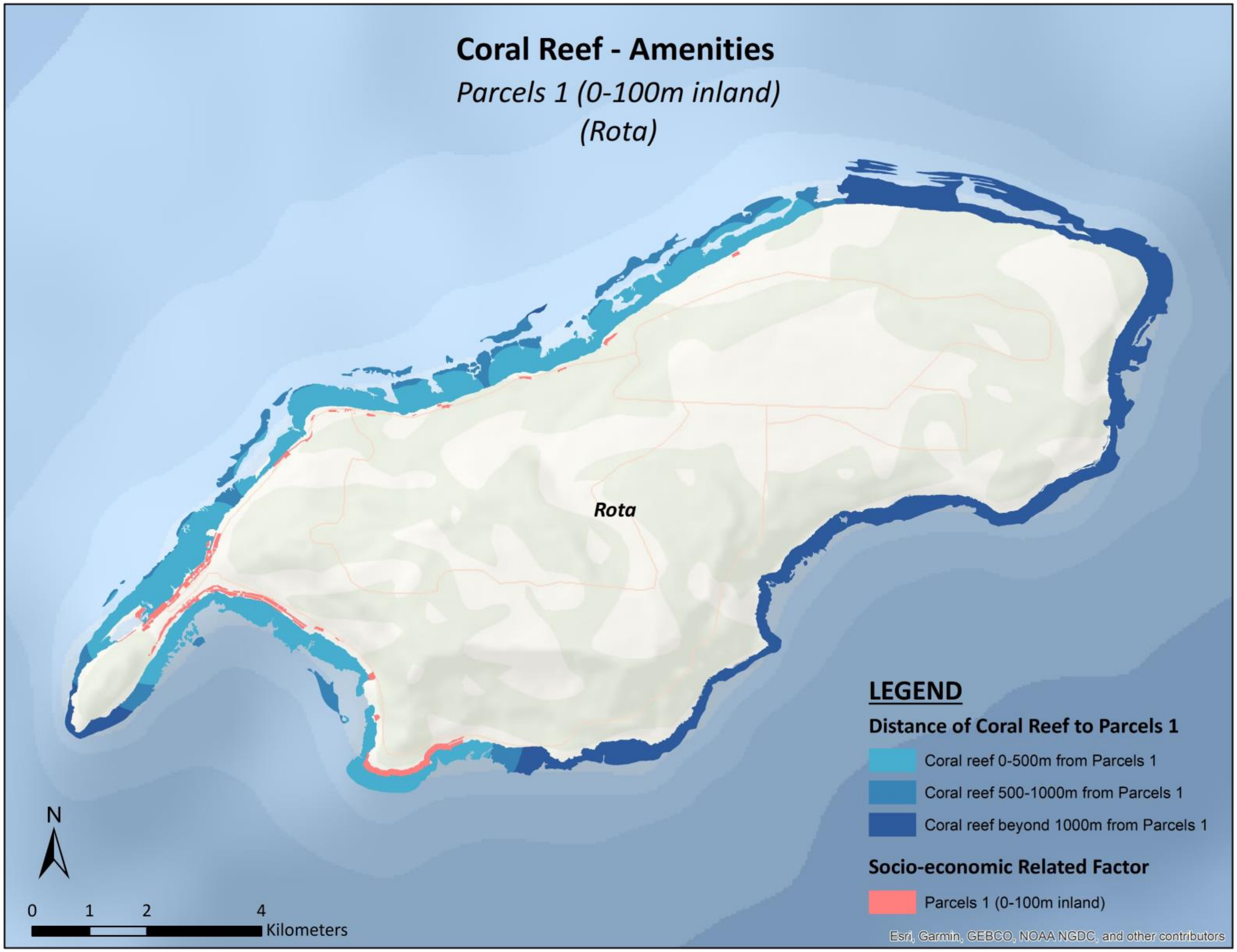



**Figure 15. Distribution of Coral Reefs in Relation to Parcels 0-100 Meters Inland, Rota**

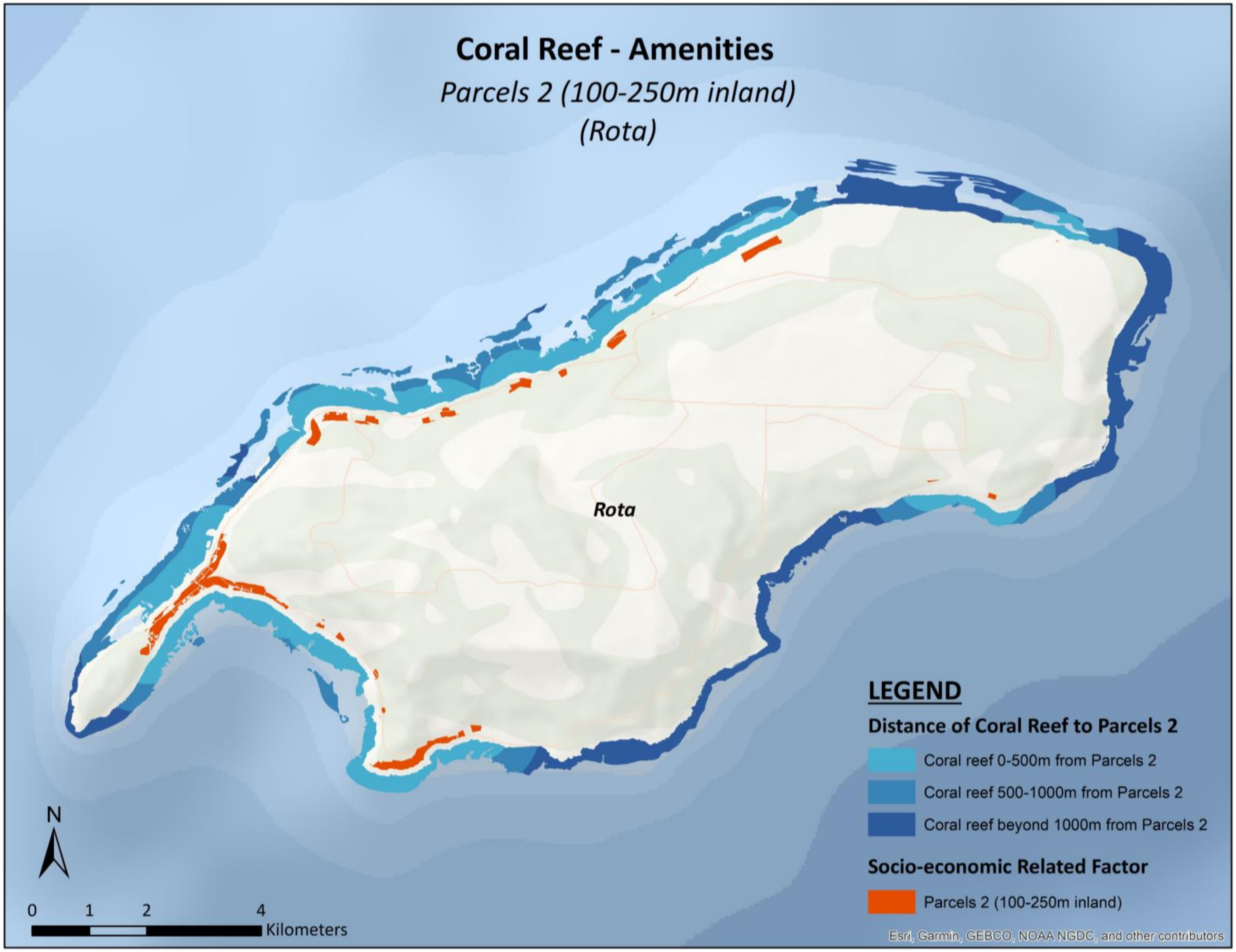



**Figure 16. Distribution of Coral Reefs in Relation to Parcels 100-250m Meters Inland, Rota**

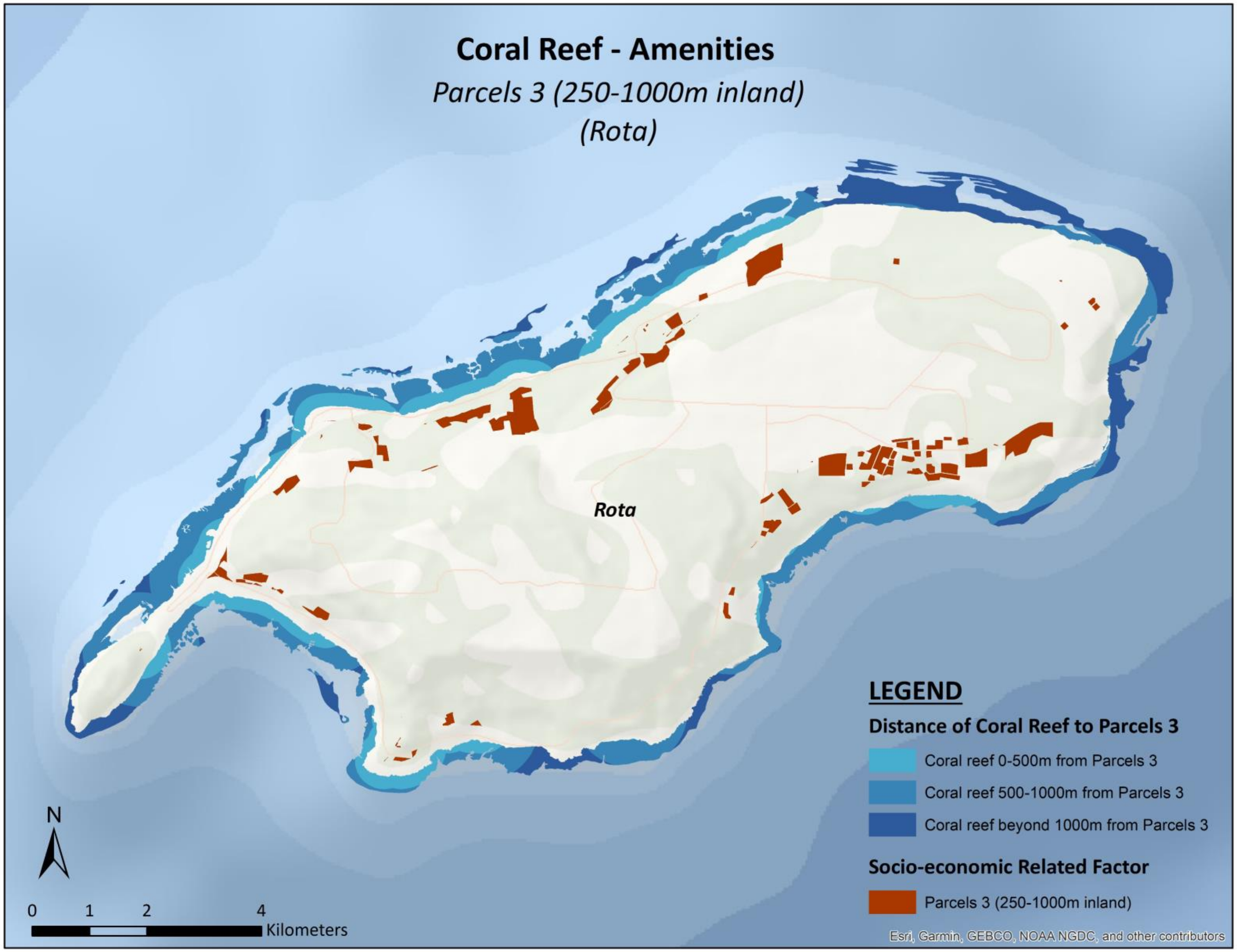



Figure 17. Distribution of Coral Reefs in Relation to Parcels 250-1000m Meters Inland, Rota


**Figure 18. Distribution of Coral Reefs in Relation to Parcels 0-100m Meters Inland, Tinian**


Figure 19. Distribution of Coral Reefs in Relation to Parcels 100-250m Meters Inland, Tinian

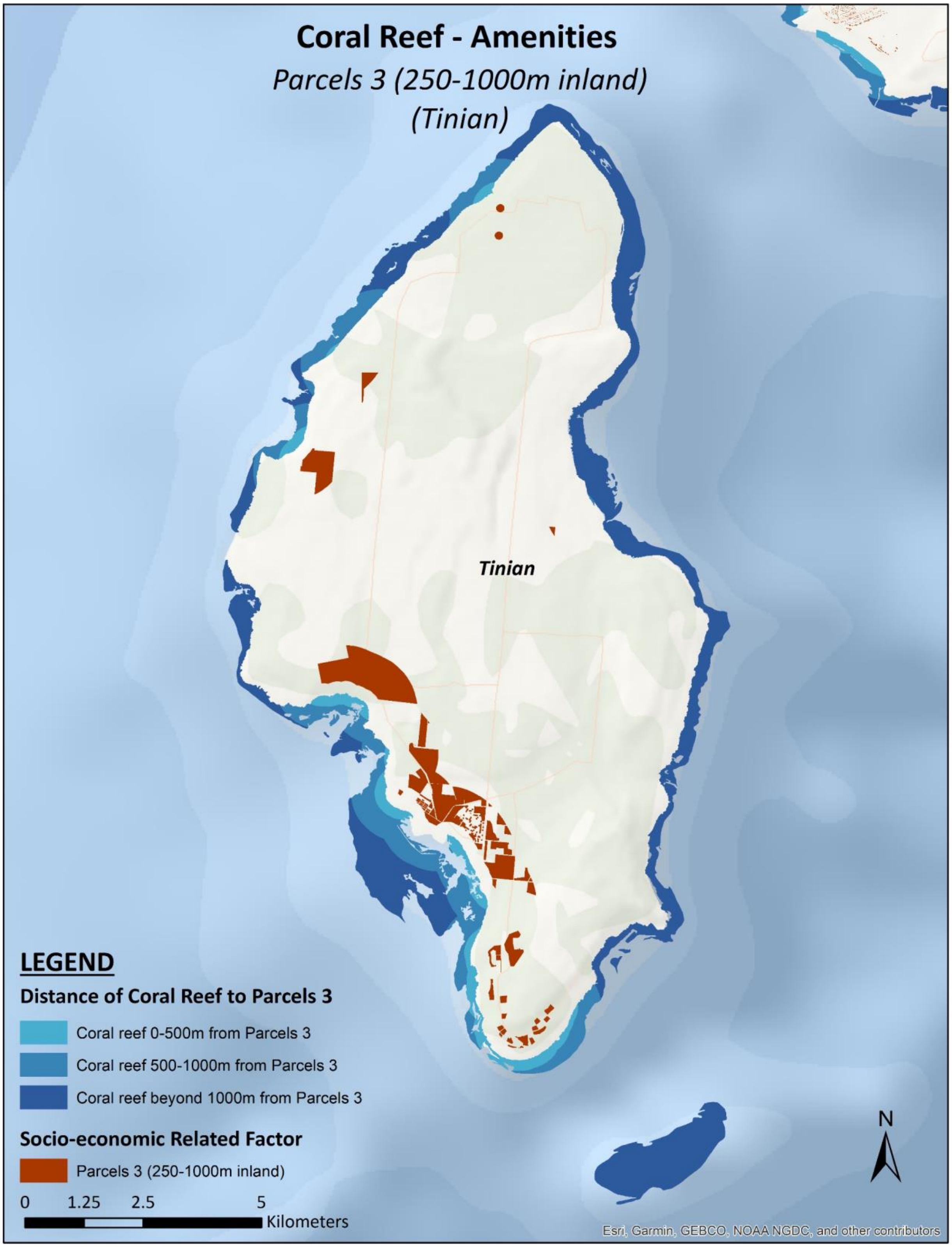



Figure 20. Distribution of Coral Reefs in Relation to Parcels 250-1000m Meters Inland, Tinian

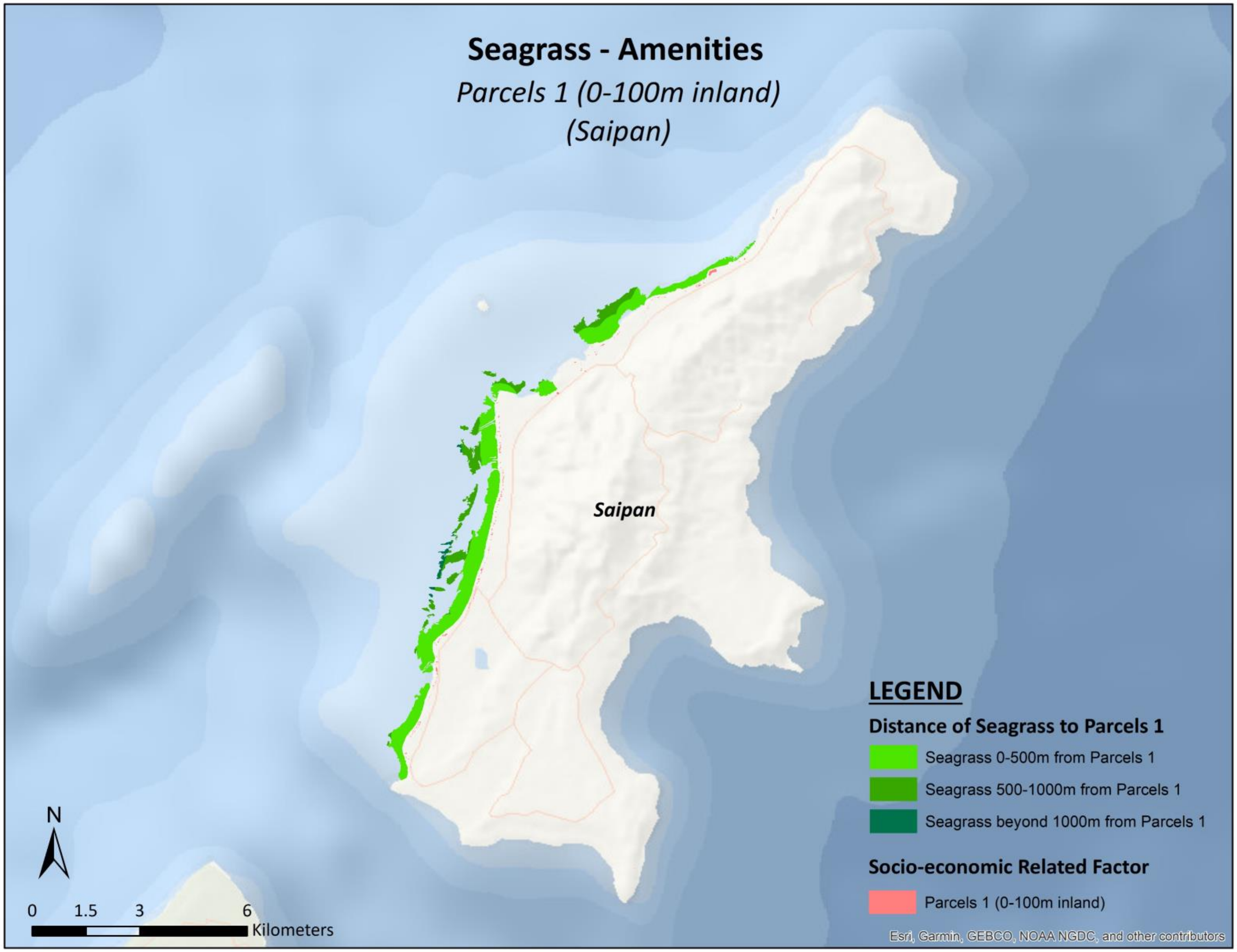



**Figure 21. Distribution of Seagrass in Relation to Parcels 0-100m Meters Inland, Saipan**

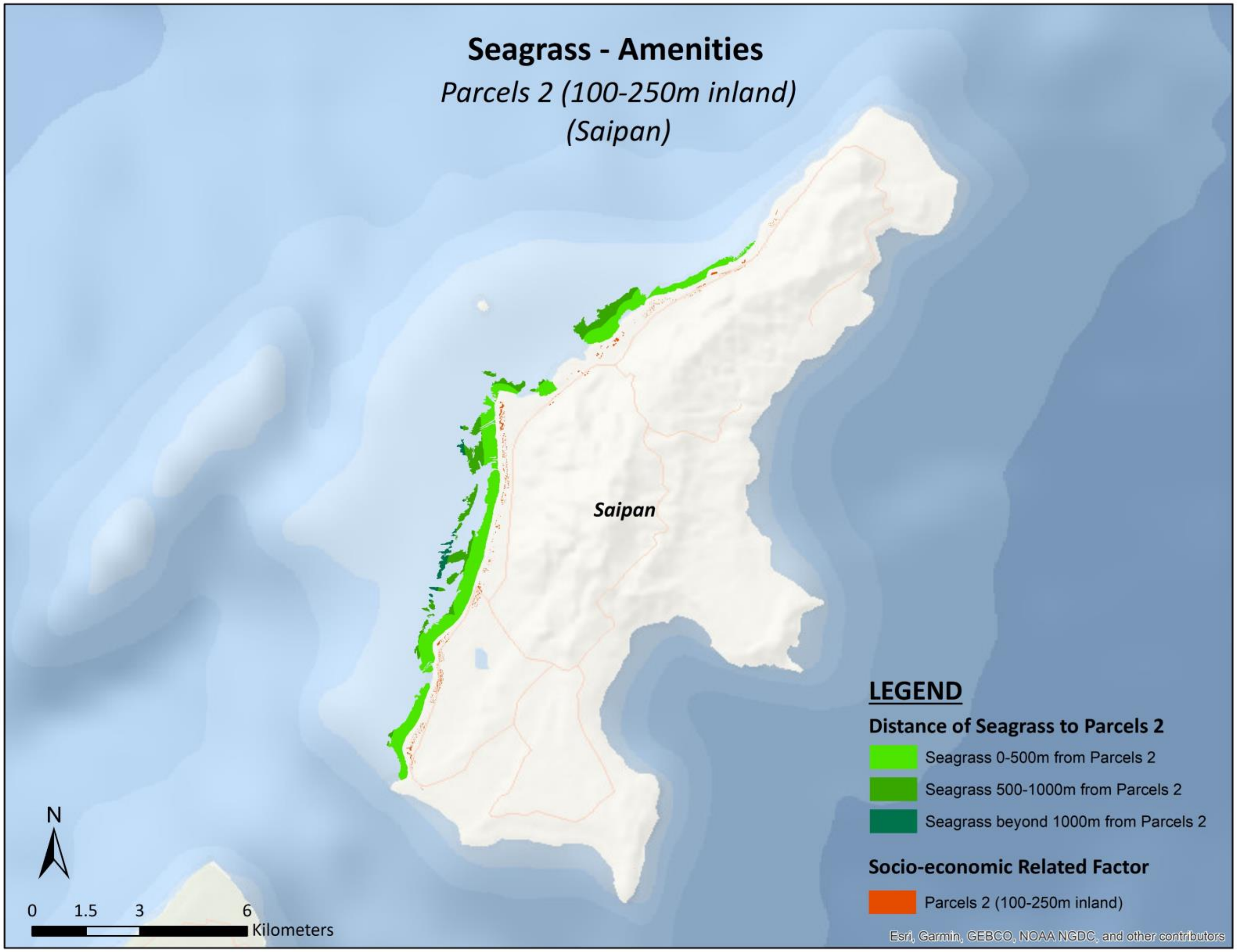



**Figure 22. Distribution of Seagrass in Relation to Parcels 100-250m Meters Inland, Saipan**

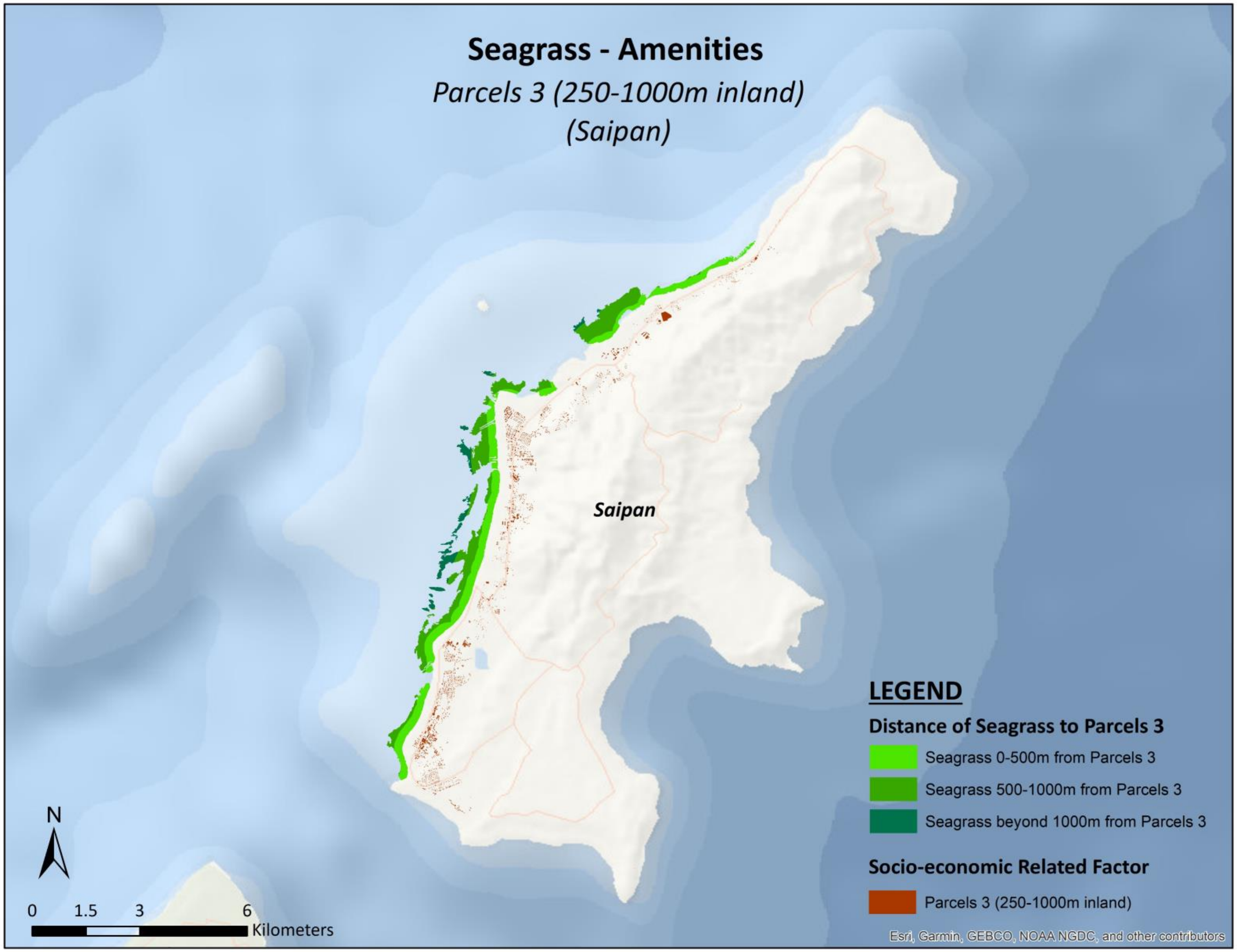



**Figure 23. Distribution of Seagrass in Relation to Parcels 250-1000 Meters Inland, Saipan**

## 7.0 Biodiversity: Research and Non-Research Related Values

The 2006 report provided an estimate for biodiversity-related research values but did not cover the value of biodiversity beyond research. To estimate the value of biodiversity-related research, the 2006 report used the total amount of research grants extended to CNMI over the period 1999-2005 as the basis for their research valuation. The three donor organizations (Environmental Protection Agency (EPA), DFW, and NOAA) invested just over $5.5 million in CNMI projects during the period 1999-2005. Thus, an annual estimate was calculated by dividing the total dollar amount of research grants given ($5.5 million) by the number of years that money was granted to CNMI (7 years), resulting in an annual estimate of $788,722 per year.

ERG estimated research and non-research biodiversity values for coral reefs and seagrass habitats on CNMI. These estimates were obtained by using known areas of coral reef and seagrass habitats on CNMI and research and non-research biodiversity values obtained from other pacific regions. For coral reefs, both research and non-research biodiversity estimates were produced for the Islands of Saipan, Tinian, and Rota, as well as an estimate for all of CNMI, while for seagrass habitats an estimate was produced for the Island of Saipan. No values for non-research biodiversity of seagrass habitats were found, so no estimate was produced.

The coral reef research values were based on annual per hectare research values from the Philippines, French Polynesia, and Australia ($53, $117, and $61.03 respectively) (Samonte-Tan et al., 2007; Charles, 2005; and Driml, 1994). To obtain the Saipan, Tinian, Rota, and CNMI annual research values, the three pacific regional values were averaged to obtain an average research value of $77 USD/hectare/year. This value was multiplied by the total coral reef habitat area (10,535 hectares) resulting in an estimated value of $811,300.

The coral reef non-research biodiversity values were based on annual per hectare non-research biodiversity values from the Philippines and French Polynesia ($174 and $50 respectively) (Samonte-Tan et al., 2007 and Charles, 2005). To obtain the Saipan, Tinian, Rota, and CNMI annual research values, the two pacific regional values were averaged to obtain an average non-research biodiversity value of $112 USD/hectare/year. This value was multiplied by the total coral reef habitat area (10,535 hectares) resulting in an estimated value of $1,179,900.

The Saipan seagrass habitat research value was based on an annual per hectare research value of $211 for Malaysian seagrass habitats (Thia-Eng, 1999). This value was multiplied by Saipan's total seagrass habitat area (6,670 hectares) resulting in an estimated value of $140,700. The maps representing the types of coral reefs and seagrass that were valued appear in the base maps that are found in Section 1.3.

**Table 19. Distribution of Estimated Biodiversity Research Value by Type of Coral**

| Category | Weight | Area ($km^2$) | Weighted Score | Estimated Biodiversity Research Value | Annual value per $km^2$ |
|---|---|---|---|---|---|
| Living coral | 7 | 46.83 | 23.41 | $579,200 | $12,369 |
| Coralline algae | 5 | 18.20 | 6.50 | $160,800 | $8,836 |
| Turf algae | 1 | 24.22 | 1.73 | $42,800 | $1,767 |
| Macroalgae | 1 | 16.10 | 1.15 | $28,500 | $1,770 |

**Table 20. Distribution of Estimated Biodiversity Non-Research Value by Type of Coral**

| Category | Weight | Area ($km^2$) | Weighted Score | Estimated Biodiversity Non-Research Value | Annual value per $km^2$ |
|---|---|---|---|---|---|
| Living coral | 7 | 46.83 | 23.41 | $842,400 | $17,990 |
| Coralline algae | 5 | 18.20 | 6.50 | $233,800 | $12,848 |
| Turf algae | 1 | 24.22 | 1.73 | $62,300 | $2,572 |
| Macroalgae | 1 | 16.10 | 1.15 | $41,400 | $2,571 |

## Next Steps

ERG recommends that BECQ-DCRM perform additional research on approaches to value research and non-research biodiversity values. ERG was able to extract information from prior studies for these estimates, but a study that focused solely on this topic based in CNMI would be warranted.

## 8.0 Coastal Protection

The economic value estimates for coastal protection were based on a wholly new method compared to the 2006 report. ERG's estimates for the value of coastal protection from coral reefs are drawn directly from Storlazzi et al. (2019). The Storlazzi study involved a comprehensive GIS modeling process to develop estimates of flooding and surge-related impacts from storms. The methods used by Storlazzi et al. (2019) involves a three-step stage process with multiple steps within each stage. The three stages can be described as follows:

- Projecting coastal hazards – In the first part of the analysis, Storlazzi et al. (2019) project storm conditions on the study areas using historical data from the Global Ocean Wave database and using the Simulating Waves Nearshore (SWAN) model. This resulted in projected storm conditions for the study area for multiple storm return intervals.
- Accounting for the effect of coral reef ecosystems – The second stage of the analysis then accounted for the effect of coral reefs on wave propagation. The modeling process generated detailed information spatially and temporally on how coral reefs affected the storm waves predicted in the first stage. This stage resulted in estimates in flooding and wave heights on the land. The study estimates flooding and wave impacts with and without coral reefs.
- Quantifying social and economic impacts – In the final stage, population, built infrastructure, and economic activity data are combined to estimate economic impacts. Specifically, the study estimates the number of people affected by flooding, the value of buildings impacted by flooding (using depth-damage curves), and the value of economic activity affected by the flooding.[11]

The study covers U.S. coral reefs in Hawaii, Florida, Guam, American Samoa, Puerto Rico, the Virgin Islands, and CNMI. Overall this covers more than 3,100 kilometers of U.S. shorelines modeled at 10 square meter resolution. They found that coral reefs are responsible for protecting 18,180 people from flooding, avoiding damages of $825 million (2010 USD) to more than 5,694 buildings, and avoiding $700 million (2010 USD) in economic activity. Furthermore, the study provides estimates for Saipan and Tinian specifically and provides detailed estimates of the avoided damages by building type for different storm return intervals as well as annualized. The study found that the benefits provided by coral reefs around CNMI (Saipan and Tinian) would be $5.7 million (2010 USD) in avoided building damages and $8.2 in avoided economic losses (2010 USD) (see Table 9 of their report).

In using these values, we make two updates. First, we updated from 2010 USD used in the study to 2018 USD to be consistent with the estimates in this report. Second, we expanded the estimates in the report to include estimates of the value of building contents that were also lost due to flooding impacts.

[11] The value of economic activity is calculated using per-capita Gross Domestic Product estimates and applying those value to the number of people per business in flooded areas.

Table 21 contains a summary of the estimates from the Storlazzi et al. (2019) study broken out by type of building.[12] Next, we used data from Huizinga et al. (2017) to estimate the value of content losses. Huizinga et al. (2017) estimate that the value of content losses is 50 percent for residential buildings, 100 percent for commercial buildings, and 150 percent for industrial buildings.[13] Finally, we updated the values of 2018 USD using the CPI. The value of lost economic activity was also updated to 2018 USD using the CPI. Thus, ERG estimates that coral reefs are associated with $21.2 million in storm protection benefits. Table 22 provides a distribution of these data across coral reef areas. The maps that distribute the estimates spatially can be found in Figure 24 to Figure 27

**Table 21. Estimated Value of Coastal Protection from Coral Reefs**

| Category | Type | Annual Estimate Calculated from Storlazzi et al. (2019) | Annual Value Including Value of Building Contents | Estimated Value Updated to 2018 USD |
|---|---|---|---|---|
| Damages to Built Infrastructure | Residential | $2,702,953 | $4,054,430 | $4,703,138 |
| | Commercial | $2,052,425 | $4,104,850 | $4,761,626 |
| | Industrial | $168,843 | $422,108 | $489,645 |
| | Other | $751,462 | $1,502,924 | $1,743,392 |
| | Total | $5,675,683 | $10,084,311 | $11,697,801 |
| Economic Activity | All | $8,193,633 | - | $9,504,614 |
| **Total Value of Storm Protection** | **-** | **-** | **-** | **$21,202,415** |

Source: Storlazzi et al. (2019)

The study itself lists a number of limitations, however, two of those are particularly relevant for this report. First, the data on the value of buildings was based on 2010 data. As CNMI has noted, a number of development projects have taken place since 2010 and thus additional properties are currently being protected. Second, the value of economic activity is based on multiplying the number of persons per business (15.1, based on U.S. as a whole data) by per-capita GDP from available data. ERG notes that the per capita GDP would include non-workers (e.g., children) as well, and may not be the best approach to calculate lost economic value.

[12] These estimates are not presented explicitly in the study. ERG calculated these values by the using the building type-specific values presented in the study and calculating the annual values from the presented data. The "other category" combined educational, religious, agricultural, and government buildings.

[13] The commercial loss rate was applied to the "other" category.

Table 22. Distribution of Coastal Protection Value for Coral Reefs Across Distance Between Coral Reefs & Parcels

| Category | Sub-category | Weight | Area (km²) | Weighted Score | Annualized Value | Annual value per km² |
|---|---|---|---|---|---|---|
| Reef layer 1 (Parcels 1) | 0-500m from parcels | 7 | 2.00 | 14.01 | $832,664 | $416,062 |
| | 500-1000m from parcels | 2 | 7.00 | 14.00 | $832,351 | $118,875 |
| | Beyond 1,000 meters | 1 | 98.35 | 98.35 | $5,845,475 | $59,437 |
| Reef layer 2 (Parcels 2) | 0-500m from parcels | 7 | 1.20 | 8.38 | $497,931 | $416,062 |
| | 500-1000m from parcels | 2 | 6.87 | 13.74 | $816,765 | $118,875 |
| | Beyond 1,000 meters | 1 | 97.28 | 97.28 | $5,782,135 | $59,437 |
| Reef layer 3 (Parcels 3) | 0-500m from parcels | 7 | 0.20 | 1.39 | $82,894 | $416,062 |
| | 500-1000m from parcels | 2 | 4.41 | 8.83 | $524,786 | $118,875 |
| | Beyond 1,000 meters | 1 | 100.73 | 100.73 | $5,987,415 | $59,437 |
| **0 – 500m from Parcels** | | - | **3.40** | - | **$1,413,488** | **$416,062** |
| **500 – 1000m from Parcels** | | - | **18.29** | - | **$2,173,901** | **$118,875** |
| **Beyond 1,000 meters** | | | **296.36** | | **$17,615,026** | **$59,437** |
| **Total for Coral Reefs** | | - | **318.05** | - | **$21,202,415** | **$66,664** |

## Next Steps

Although the study we used to develop these estimates was based on a very recent report and developed estimates specific to CNMI, there are areas where BECQ-DCRM can improve on the estimates from the report. Specifically, the Storlazzi study used older data on the building stock on the islands that did not include newer developments. ERG recommends that BECQ-DCRM review the study data source in detail and recreate the analysis using the modeling in study with the most current data available. BECQ-DCRM reports that by 2020, CNMI will have 2-3 meter resolution topo-bathy LiDAR for Saipan, Tinian, and Rota, and this data should be leveraged and combined with updated critical facility data and run-up and surge scenarios to update this assessment using best available data.

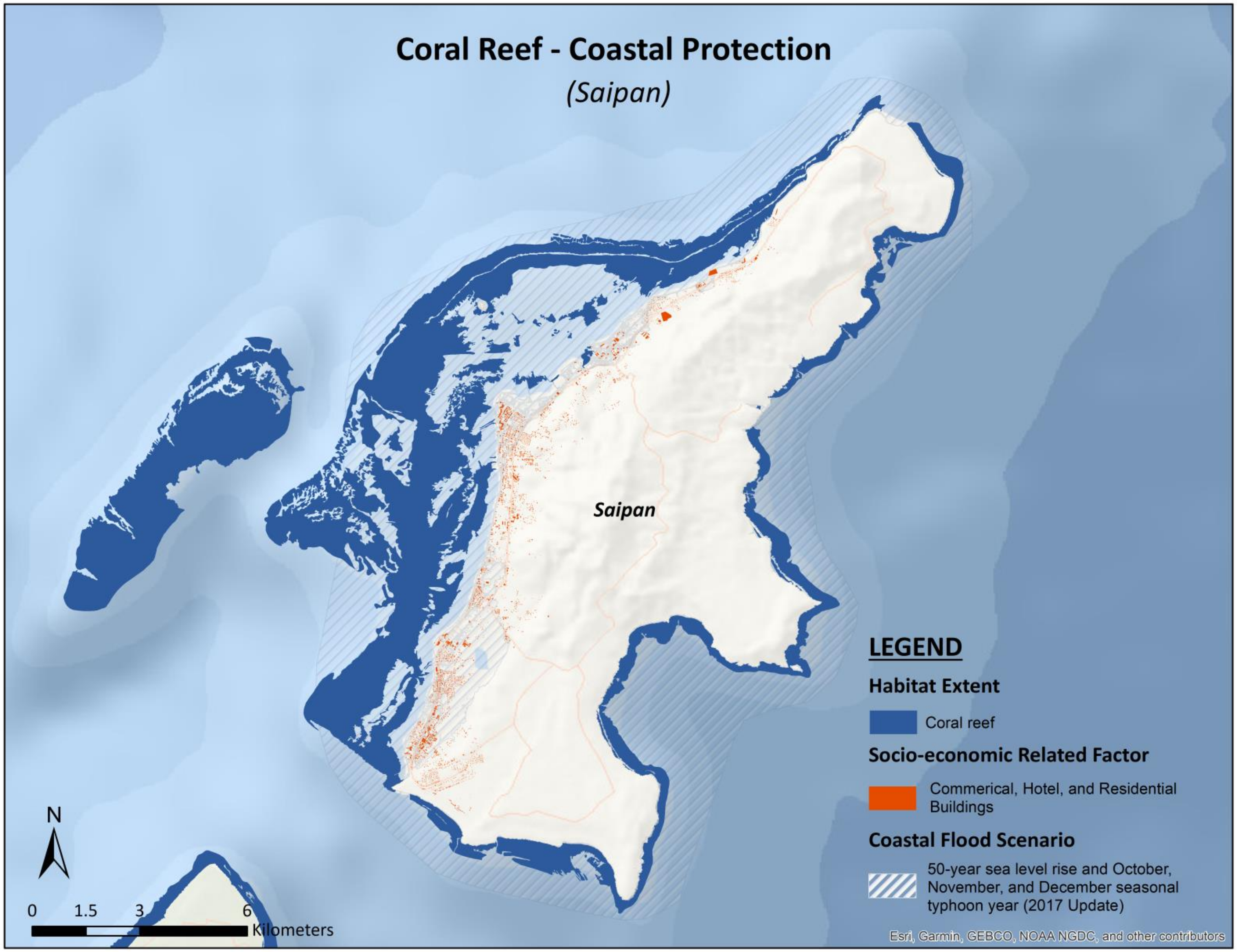



**Figure 24. Distribution of Coral Reefs, Buildings, and the Coastal Flood Scenario on Saipan**

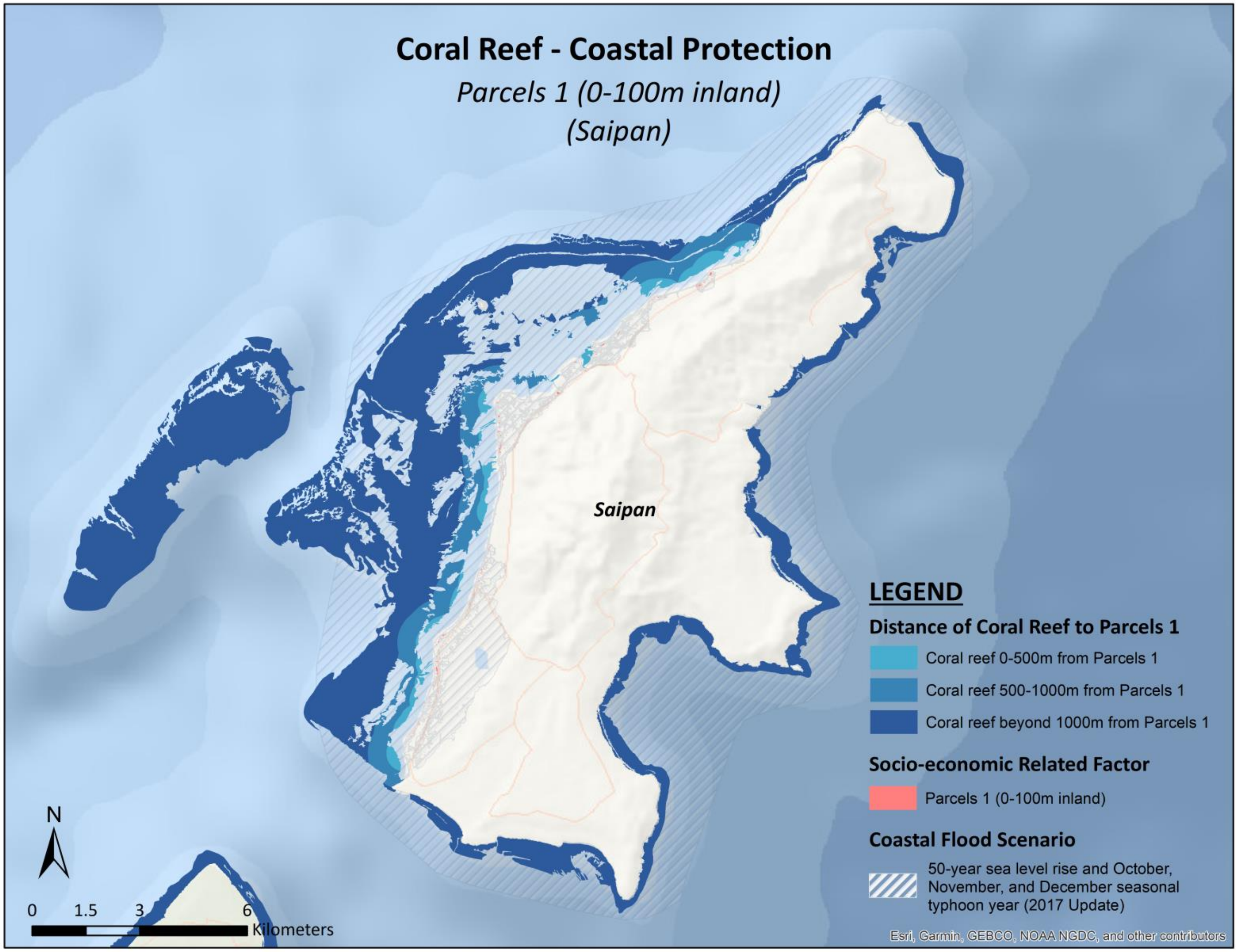



Figure 25. Coral Reef Distances from Structures 0 – 100m Inland, Saipan

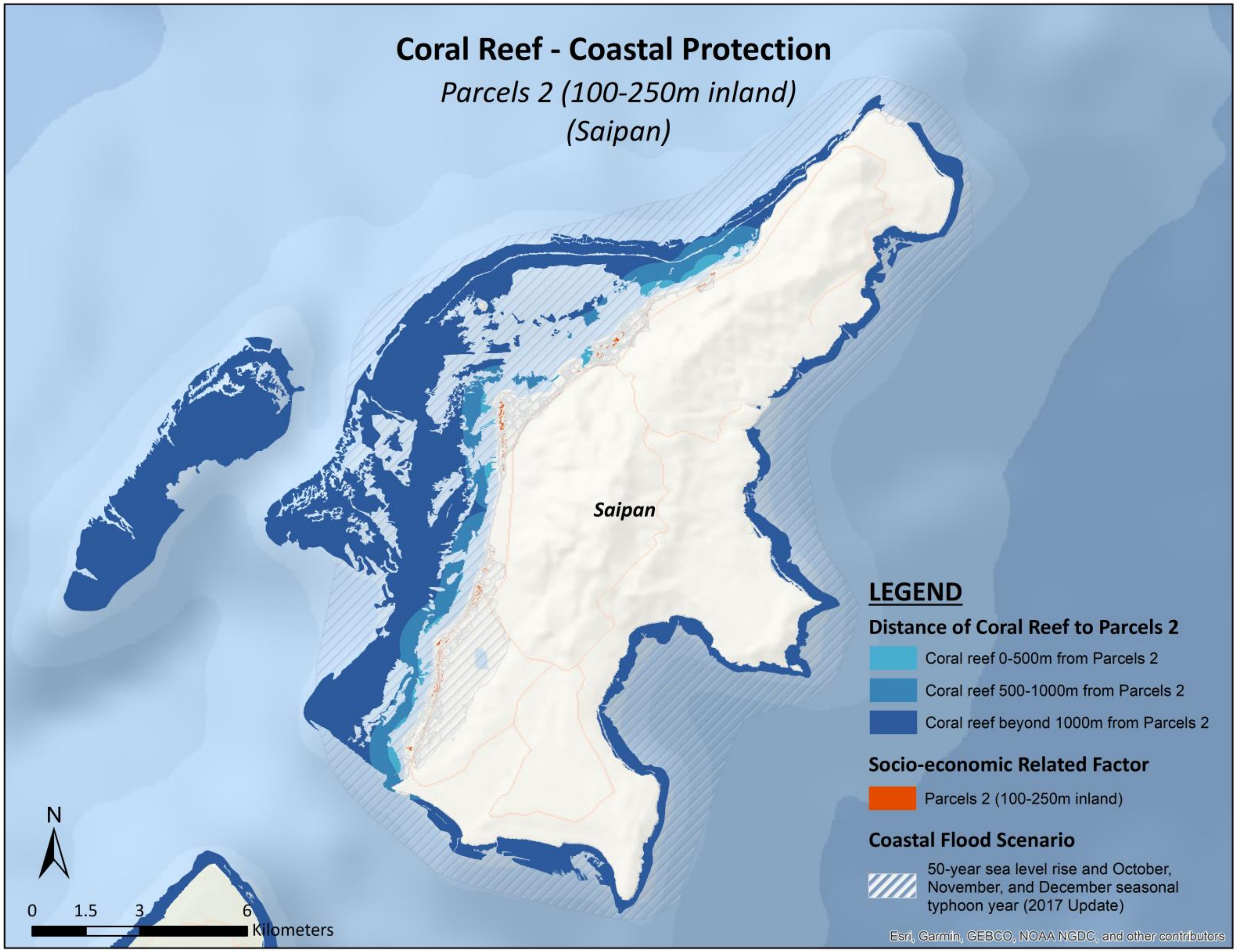



**Figure 26. Coral Reef Distances from Structures 100 – 250m Inland, Saipan**

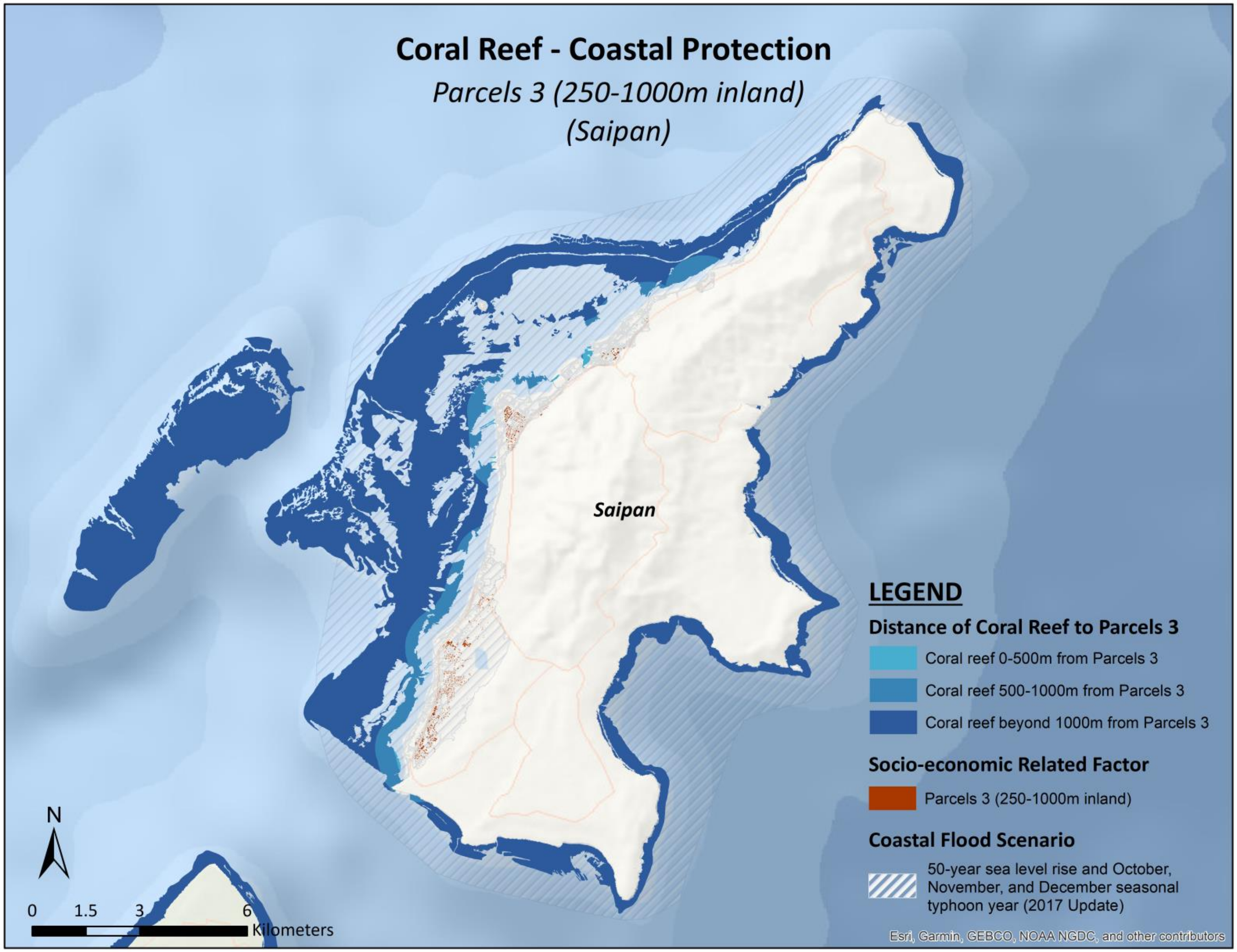



Figure 27. Coral Reef Distances from Structures 250 – 1000m Inland, Saipan

## 9.0 Summary

This report has provided estimates of the total economic value of ecosystem services provided by coral reefs of Saipan, Rota, and Tinian and seagrass of Saipan. This report updates a 2006 report commissions by CNMI which focused on only the coral reefs of Saipan. The primary approach has been to develop these estimates based on benefit transfer estimates. The report developed estimates for seven ecosystem services:

- Commercial fishing,
- Non-commercial fishing by residents,
- Tourism and recreation,
- Amenity/property value,
- Research,
- Biodiversity, and
- Coastal protection

Additionally, except or commercial and non-commercial fishing, the report has provided spatial distributions of the estimated economic values in terms of maps that appear throughout the report.

Table 23 provides a summary of the estimates provided in this report. Across all ecosystem services, the coral reefs of CNMI generate $104.5 million annually in economic value and the seagrass of Saipan generates an additional $10.3 million in value. In total the coral reefs and seagrass in CNMI generate an annual value of $114.8 million. Figure 28 provides a chart showing the distribution of the total estimated value (coral reefs plus seagrass) over the ecosystem services. As can be seen, the predominant values are foreign tourism (64.1 percent of the total, producer plus consumer surplus) and coastal protection (18.5 percent); combined these two generate 83 percent of the total annual value. ERG recommends that CNMI continue to update existing data sources and fill data gaps as outlined in this report to support at least decadal updates of eco-valuation data for resource management purposes in the CNMI.

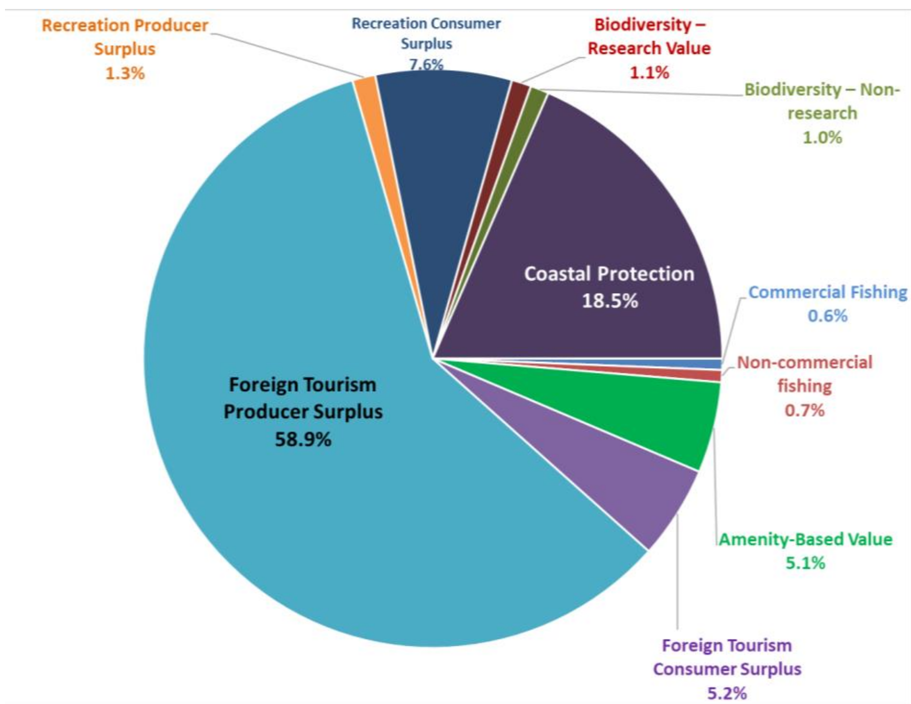



Figure 28. Distribution of Ecosystem Service Values

Table 23. Summary of Total and Per-Hectare Ecosystem Service Value Estimates

| Ecosystem Service | Habitat | Distribution Factor /Type | Total Value Per Year | Value per Hectare per Year |
|---|---|---|---|---|
| **Commercial Fishing** | **Coral Reefs** | ***Total*** | ***$688,600*** | ***$65*** |
| | **Seagrass** | ***Total*** | ***$43,600*** | ***$65*** |
| **Non-commercial fishing (recreational and subsistence)** | **Coral Reefs** | ***Total*** | ***$731,800*** | ***$69*** |
| | **Seagrass** | ***Total*** | ***$46,300*** | ***$69*** |
| **Foreign Tourism Producer Surplus** | **Coral Reefs** | *0-500m from access* | *$39,316,100* | *$1,110,300* |
| | | *500 – 1,000m from access* | *$11,732,300* | *$616,800* |
| | | *1,000 – 1,500m from access* | *$4,396,800* | *$370,100* |
| | | *More than 1,500* | *$4,816,300* | *$123,400* |
| | | ***Total*** | ***$60,261,500*** | ***$572,000*** |
| | **Seagrass** | *0-500m from access* | *$7,405,800* | *$1,110,300* |
| | | ***Total*** | ***$7,405,800*** | ***$1,110,300*** |
| **Foreign Tourism Consumer Surplus** | **Coral Reefs** | *0-500m from access* | *$3,470,600* | *$98,000* |
| | | *500 – 1,000m from access* | *$1,035,300* | *$54,400* |
| | | *1,000 – 1,500m from access* | *$388,100* | *$32,700* |
| | | *More than 1,500* | *$425,100* | *$10,900* |
| | | **Total** | **$5,319,100** | **$50,500** |
| | **Seagrass** | *0-500m from access* | *$653,600* | *$98,000* |
| | | **Total** | **$653,600** | **$98,000** |
| **Recreation Producer Surplus** | **Coral Reefs** | *0-100m of mooring buoys* | *$859,800* | *$24,300* |
| | | *100-200m of mooring buoys* | *$256,600* | *$13,500* |
| | | *200-300m of mooring buoys* | *$96,200* | *$8,100* |
| | | *Beyond 300m of mooring buoys* | *$105,300* | *$2,700* |
| | | **Total** | **$1,317,900** | **$12,500.00** |
| | **Seagrass** | *0-500m from access* | *$162,000* | *$24,300* |
| | | **Total** | **$162,000** | **$24,300** |
| **Recreation Consumer Surplus** | **Coral Reefs** | *0-100m of mooring buoys* | *$5,071,200* | *$143,200* |
| | | *100-200m of mooring buoys* | *$1,513,300* | *$79,600* |
| | | *200-300m of mooring buoys* | *$567,100* | *$47,700* |
| | | *Beyond 300m of mooring buoys* | *$621,200* | *$15,900* |
| | | **Total** | **$7,772,800** | **$73,800** |
| | **Seagrass** | *0-500m from access* | *$955,200* | *$143,200* |
| | | **Total** | **$955,200** | **$143,200** |

| Ecosystem Service | Habitat | Distribution Factor /Type | Total Value Per Year | Value per Hectare per Year |
|---|---|---|---|---|
| **Amenity-Based Value** | **Coral Reefs** | *0 – 500m from Parcels* | *$1,946,229* | *$61,806* |
| | | *500 – 1000m from Parcels* | *$872,807* | *$17,659* |
| | | *Beyond 1,000 m from parcels* | *$2,093,193* | *$8,829* |
| | | **Total** | **$4,912,228** | **$15,448** |
| | **Seagrass** | *0 – 500m from Parcels* | *$808,653* | *$61,806* |
| | | *500 – 1000m from Parcels* | *$109,412* | *$17,659* |
| | | *Beyond 1,000 m from parcels* | *$8,606* | *$8,829* |
| | | **Total** | **$926,672** | **$45,752** |
| **Biodiversity – Research Value** | **Coral Reefs** | *Living coral* | *$799,400* | *$17,072* |
| | | *Coralline algae* | *$221,900* | *$12,194* |
| | | *Turf algae* | *$59,100* | *$2,440* |
| | | *Macroalgae* | *$39,300* | *$2,440* |
| | | **Total** | **$1,119,700** | **$10,600.00** |
| | **Seagrass** | **Total** | **$140,700** | **$211.00** |
| **Biodiversity – Non-research** | **Coral Reefs** | *Living coral* | *$842,400* | *$17,990* |
| | | *Coralline algae* | *$233,800* | *$12,848* |
| | | *Turf algae* | *$62,300* | *$2,572* |
| | | *Macroalgae* | *$41,400* | *$2,571* |
| | | **Total** | **$1,179,900** | **$11,200** |
| **Coastal Protection** | **Coral Reefs** | *0 – 500m from Parcels* | *$1,413,488* | *$1,171,372* |
| | | *500 – 1000m from Parcels* | *$2,173,901* | *$334,678* |
| | | *Beyond 1,000 m from parcels* | *$17,615,026* | *$167,339* |
| | | **Total** | **$21,202,415** | **$66,700** |
| **Grand Totals** | **Coral Reefs** | | **$104,505,943** | - |
| | **Seagrass** | | **$10,333,872** | - |
| | **Total** | | **$114,839,815** | - |

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