




2019 State of the Environment Report Republic of Palau

April 2019

An independent report presented to the President of the Republic of Palau

by the
National Environmental Protection Council (NEPC)

Prepared by Anuradha Gupta

Dear President,

On behalf of the National Environmental Protection Council (NEPC), I am pleased to present you with this 2019 State of the Environment Report. Our previous 2017 State of the Environment Report was an important and impactful document that spurred action in Palau and was emulated by others in the Pacific.

Palau's comprehensive effort to catalog, attach meaning, and act on research and monitoring data piqued the interest of community members and researchers, who actively sought to be included in this new 2019 Report. Thus this 2019 State of the Environment Report is even more detailed and comprehensive than the previous one. Because of the inclusion of new Indicators and information, this Report does not just cover the period from 2017 to 2019, but goes back years to decades in order to provide a thorough picture of conditions and trends. The Report was widely reviewed before completion, and I am pleased that a wide array of scientists and resource managers agree that it presents an accurate and actionable snapshot of Palau's marine, terrestrial, and human/urban environment and resources in 2019.

New in this report is a stronger emphasis on the human element of the environment. It discusses the meaning of environmental indicators in daily human lives, and provides a better picture of the organizations and agencies that are working in various sectors.

As in 2017, where we have invested, we have healthy conditions and trends. Where we–as a National Government–have not taken the lead, such as Nearshore Fisheries, our resources are in trouble. This Report provides a clear picture of where our priorities need to shift in order to provide for the Palauan people and our future generations.

Sincerely,

Minister Umiich Sengebau
Chair
National Environmental Protection Council

Contents

Photo courtesy of BWA/R2R

Cover photos, clockwise from top left: Koror-Airai Bridge © Shutterstock/HighD; M-Dock Painting by A. Gupta; Woman at Spring courtesy of BWA/R2R; Solar Panels courtesy of Palau Energy Office; Dock from underwater © Shutterstock/Ethan Daniels; Taro courtesy of BWA/R2R.

Introduction & Summary

Photo by A. Gupta

Introduction

This 2019 State of the Environment Report (SOE) conveys trends of key natural resource and human response indicators through time, and analyzes their most recent conditions and grades in relation to local and global goals and standards. Where possible, it interprets meaning and assigns a Condition or Grade—Good to Poor—and uses a color-coding system to convey whether indicators are healthy. It applies the same color coding system to show if a trend is beneficial or harmful to the environment. This report fulfills annual reporting requirements of the NEPC. This 2019 SOE follows up on the 2017 SOE, and was reorganized to include State, Pressure, and Response to key marine, land, and urban habitats and sectors. Climate Change and Invasive Species are addressed as pressures in multiple sectors; Protected Areas are reported on as a response (and addressed separately for marine and terrestrial habitats).

Summary

114 Indicators are presented; for each Indicator, several lower-level indicators were assessed. 91% of Indicators (up from 82% in 2017) had adequate information to assign a condition, grade, or trend.

Marine: 62 marine indicators were assessed. 55% of indicators were in good or fair condition or with a healthy trend; this is a decrease since 2017 largely in part to increased information and declining nearshore fisheries.

Terrestrial: 24 terrestrial indicators were assessed. 75% of indicators were in good or fair condition or had a healthy trend; this is an increase from 2017 due both to new information and successful initiatives.

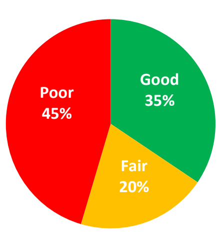
Protected Areas: Protected Areas (PA) indicators were revised significantly. 8 marine, mangrove, terrestrial, and bird PA indicators were assessed. 84% had a good or fair grade; but 16% were poor (the 2017 SOE had 100% good or fair, prior to revisions).

Human/Urban: 26 human/urban indicators were assessed. 72% of indicators had a good or fair grade or with a healthy trend; this is the same as in 2017.

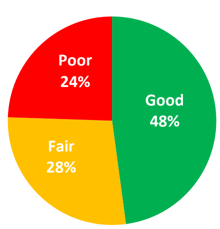
Coral Reefs

Most shallow coral reefs are in good condition. Shallow reefs on the East Coast and deeper reefs (newly addressed in this SOE) are not in good condition. Many of the pressures on coral reefs are intense and getting worse. Global climate change has immediate negative impacts on coral health. Local pressures (such as sedimentation) are not well understood. Palau has responded well to these pressures, and continues to improve. Continued investment in MPAs (particularly the commitment by States to set aside new MPAs), means that only lagoons and reef flats are still poorly represented in Palau's network of MPAs. Responses to local pressures have been very slow and should be improved, particularly reducing sedimentation and overfishing of reef fish.

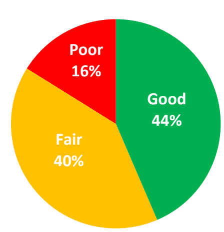
Summary of Marine Indicators



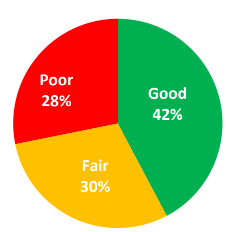
Summary of Terrestrial Indicators

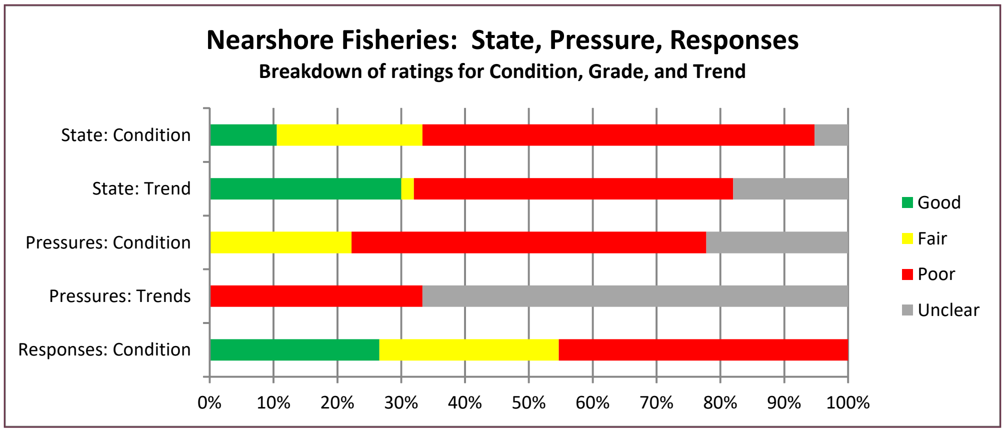


Summary of Protected Area Indicators



Summary of Human/ Urban Indicators





Figure, left (p. 22). Nearshore Fisheries are in trouble, with many species (fish and invertebrates) at risk of a local or widespread population crash. The Nearshore Fishery sector needs immediate, coordinated, direct, and socially inclusive responses. Many new sources of information were analyzed; across 186 sub-level indicators, only 20% were Good and 18% were Fair. 52% of indicators were Poor and 10% were Unclear.

Nearshore Fisheries

The majority of indicators for nearshore fisheries are in Fair to Poor condition, and getting worse (see Figure, above). There are many unknowns. Several species are at risk of a population crash (locally or widespread). It also appears that invertebrates have been overfished (locally or widespread). Pressures on Nearshore Fisheries come from local stressors as well as climate change. Palau's response to Nearshore Fisheries has been inadequate. Investment in MPAs has yielded some good results, but it is not enough. The majority of reef fishery resources are not protected via MPAs or rules and regulations, and there are key gaps in knowledge. Current alternatives to nearshore fishery use, such as aquaculture and offshore fisheries, are not yet adequate to reduce current and anticipated pressure on nearshore fisheries. Palau's National Government has invested relatively little into managing nearshore fisheries. Information on nearshore fisheries is widespread and at times, conflicting. Palau must improve its approach to Nearshore Fisheries with a comprehensive, coherent response, using the coordinated strengths of multiple actors; as it does with coral reefs. This response must also be gender and socially inclusive.

Offshore Fisheries

Palau's Offshore Fisheries are in Fair condition, in relation to stock assessments for the entire Western and Central Pacific, but appear to be improving. Pressures from climate change are expected to get worse; there is much that is unknown. Palau's overall response has been good.

Select Marine Species and Sites

In general, several marine species and sites have unhealthy trends and are getting worse. There is a lack of knowledge or monitoring programs for most marine sites and species, which limits understanding of and responses to pressures. Jellyfish Lake and its unique species are well understood and monitored. Most marine species and sites discussed here have some sort of regulation or law applied, even if inconsistently. However, compliance and enforcement must be strengthened to stop declines and reduce pressures.

Mangroves

Mangroves in Palau appear to be healthy and resilient. Over the long-term mangroves have expanded; however the impact of that growth (e.g. on rarer habitats such as seagrass) remains unknown. While baseline information on mangroves is good, there have been few follow-up studies to determine if baselines

About this report

Palau's environment and environment sector are both large and complex. This report can only present priority indicators and actions as a snapshot in time. No new field research was done for this report, although some data were analyzed anew. Indicators were pulled from published and unpublished research and monitoring programs. Standards and goals came from Palau's Strategic Plans and from literature.

Limits of this report

"The Environment" in Palau is a highly complex web of people, places, ideas, species, sites, practices, and changing conditions. Many data and analysis gaps were identified through this report's research process. Recommendations for filling baseline and/or trend gaps are included in discussions. In some cases it was not possible to determine a grade, either because standards and goals do not yet exist, or because there were conflicting interpretations of the condition or trend. For some indicators it was not possible to assign a simple "Good" or "Poor" grade to a multi-faceted condition. This report highlights where additional research is needed, and is just the starting point to making sound decisions.

Key to Color Codes

Condition or Grade: Good/Healthy. Populations are stable and/or sustainable or Ecosystems are functional and resilient; Environment allows human well-being. Responses improve conditions or reduce pressures.
Trend: Beneficial to the environment. Healthy, desired.

Condition or Grade: Fair. Populations and/or ecosystem functions could improve in condition but are not declining. Responses address conditions or pressures to some extent, but improvement is needed.

Condition or Grade: Poor/Not healthy. Populations below stable or sustainable levels, or Threatened; Ecosystems not functioning in natural state; Environment hinders well-being. Responses are ineffective at improving conditions or reducing pressures.
Trend: Harmful to environment. Unhealthy, not desired.

Condition or Grade: No grade assigned. No standards, goals, data, or consensus on which to base grade; or Unknown/information gap.
Trend: No clear trend; no data or basis to determine whether trend is beneficial or harmful. Or, Baseline.

have changed. Palau's Carbon Stocks are relatively high. Human use and clearing impacts large areas of mangrove at a time. 33% of mangroves are managed in some way, although given the importance of mangroves to food and climate security, the target for management is 75%. Mangrove MPAs appear to be performing well. National Government leadership on mangroves remains a gap.

Forests

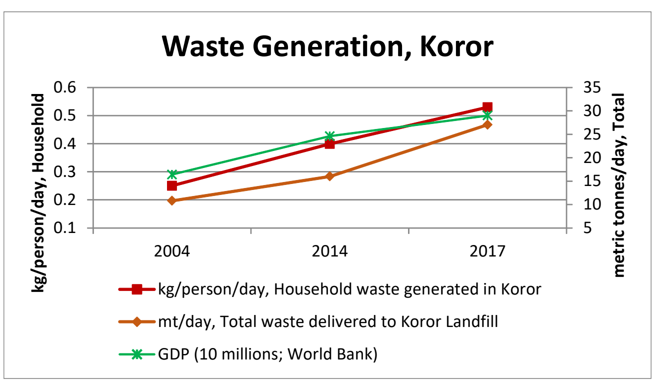
With the exception of burned areas, forests are in good condition, with high diversity. Total forest cover increased. However, trends indicate that the extent of damaged and degraded lands and forests, and the number of damaged trees, is increasing. There is little public data on uses of forests, freshwater resources, or freshwater biodiversity. Fire and climate change pose significant threats to forests. Invasive Alien Speces seem to be better controlled on land and Palau has implemented measures to reduce their threat. There is little information on human use. Extent of Terrestrial Protected Area has increased but is still too low. Performance of Terrestrial Protected Areas is fair to good for socioeconomic indicators, but unknown for biophysical indicators. Information on endemism, distribution, and status terrestrial plants has increased significantly. However, many plant species are now known to be threatened or endangered, and few are managed outside of Protected Areas.

Birds

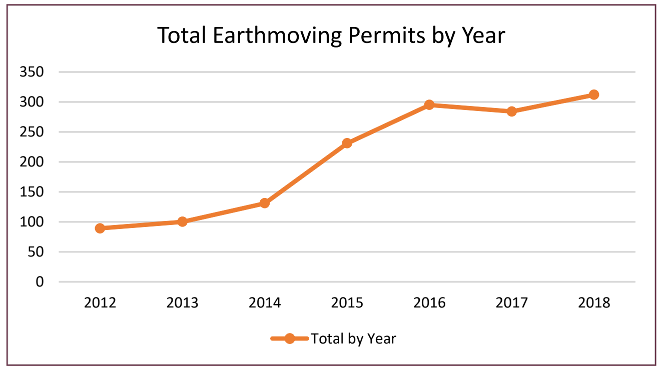
Birds are indicators of general environmental health. Many birds appear to be doing well, with the significant investment in bird conservation over the past decade leading to improved conditions and trends. After a decade of implementing bird programs, bird diversity is good, and Biib and Bekai appear to have started a recovery. The trend for Belochel is not clear. However, Melabaob has decreased. While climate change is a threat to birds, the majority of pressure on birds comes from humans. Palau's many excellent programs for birds (eradication, forest restoration, research and monitoring, outreach) have likely resulted in improving conditions. However, there is inadequate protected area for birds, and a critically important shorebird site is not protected. Data access is good, but data are not always standardized or analyzed.

Earthmoving and Development

The number of permits issued continued to increase, although this number includes changes to existing structures (e.g. renovations or improvements with little environmental impact). Both the number of violations and the violation rate increased, which may be due to increased legal capacity at EQPB or to rapid growth. The majority of development is permitted without a formal Environmental Assessment (EA) or Environmental Impact Statement (EIS). The majority of hotel growth since 2012 was small/niche. EQPB continues to review and revise its regulations. In 2017, no (0) states had comprehensive landscape and seascape plans in place; only 4 of 16 states have partial plans or some zoning.



Figure, top (p. 80). Solid Waste is increasing.



Figure, top (p. 74). The number of Earthmoving Permits was at an all-time high in 2018.

Water Resources

Treatment of drinking water (in terms of supply and quality) is good. Drinking water in the urban areas of Koror and Airai meets safe standards for Turbidity and E. Coli. However, water in the urban area occasionally (but less frequently) exceeds safe standards for total coliform, and water in rural areas regularly exceeds turbidity and coliform standards. Improvements to water and wastewater infrastructure, such as the Koror-Airai Sanitation Project and the Project for Improvement of Water Supply System, are likely contributing to decreased average fecal coliform and turbidity; and to decreased water use. Water supply is good on an annual basis, but supply varies dramatically with extreme weather. It appears that total use (and waste) may have decreased since 2010. Palau's drinking water monitoring program is excellent. However, there is little information on marine water and freshwater. Access to treated water and sanitation is almost 100%.

Solid Waste and Recycling

The amount of total waste generated is increasing, apparently at pace with GDP. The increase in total waste generated is outpacing programs to reduce, reuse, or recycle waste. Although solid waste programs are good, with collection in 100% of Koror's residential areas and numerous recycling programs, they are not able to keep up with the amount of solid waste produced. The total amount of waste recycled or composted increased, but as a proportion of total waste generated, it decreased. Increasing composting would divert significant waste. The Beverage Container Deposit and Redemption Program has successfully diverted most beverage containers from the landfill.

Agriculture

Agricultural production and participation has increased. However, there is little tracking of production, and growth appears too slow to meet demand and targets. Facilities to serve the agricultural sector have expanded, including opening of the National Slaughterhouse, identification of and support for Best Practices, expansion of agroforestry through nursery trees, and control and removal of IAS (including vines and fruit flies).

Energy Sector and Transportation

Renewable Energy (RE) and Energy Efficiency (EE) both increased, but at a pace that is too slow to meet goals. Total energy consumption increased drastically, reducing the proportion of renewable energy produced and consumed. Based on financial import data, car imports appear to have decreased.

Awareness and Capacity

Public awareness of environmental and conservation issues remains high, although may have decreased due to a shift in approach to targeting key stakeholders. The growth of PAN and the introduction of new initiatives (such as the Sustainable Tourism Framework and biennial National Environment Symposium) have brought many new people into the environment sector.

Gender and Social Inclusion

Several initiatives (e.g. Land Use Planning and Protected Areas Planning and Management) have the potential to have negative, unintended consequences on genders or social groups. The Environment Sector/Conservation Community has begun applying a Gender and Socially Inclusive Lens to projects and initiatives. Mainstreaming plans have been incorporated into existing National Projects and baselines have been established. Future National Projects will mainstream gender and social inclusion into project designs through implementation of a new Project Management Manual Handbook.

Photo courtesy of BWA/R2R

Humans and the Environment

What is the environment? In this report, "Environment" is more than fish or birds or trees. The "Environment" encompasses the human relationship to these natural resources and habitats. Palau's environment sector (natural resource managers, conservationists, businesses, community volunteers, and many others) works to protect the environment for the benefit of people–for food, money, recreation, culture, identity, and so much more.

Palau's tourism industry is reliant on the environment, with visitors coming to Palau for its splendid marine and terrestrial habitats and species. Combined with fishing, 50% of Palau's economy is directly reliant on the environment. Locally funded benefits for people–Social Security, Pensions, even hot meals for the elderly–are thus made possible by Palau's environment. Non-monetary services, such as clean air, clean water, and safe soils, are clear benefits to communities that come directly from the environment.

338	Households that used Biomass for some of their fuel needs (2015)
94	Jobs financed by the PAN Fund (2017)
494	Employees listing Occupations in Agriculture, Forestry, Mining/Quarry, Professional/Scientific, and MNRET (2017)
1,847	Employees in Accommodations/Restaurants (tourism sector) (2017)
$9.8 million	National Government income from fishing license fees (2017)
46%	Contribution to Palau's GDP from tourism (2017)
86%	Palau's tourism sector accounts for 86 percent of total export in 2016. Palau is the most tourism-concentrated countries among small states (International Monetary Fund, 2019)
5%	Importance of subsistence production (farming, fishing, livestock, and handicrafts) to rural household incomes
1,979	Number of individuals (15 years old+) who received income from crops, fish, livestock, or handicrafts (2014)
1,222	Number of individuals who received income from Social Security or Pensions (2014)

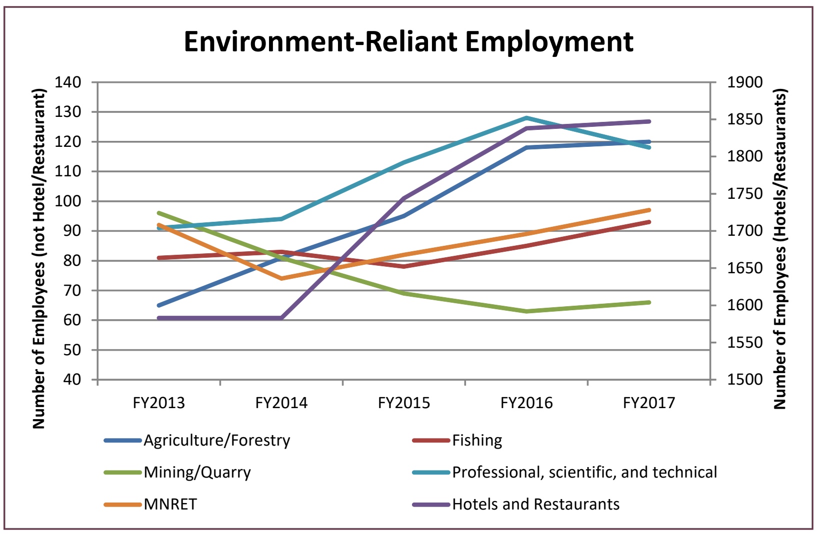


Figure (above): Number of individuals occupied in sectors reliant on the environment, including agriculture, forestry, fishing, mining, MNRET employees, Professional, Scientific, and Technical individuals, and Accommodations and Restaurants (which are driven by access to Palau's environment). Graphed from BBP (2017 - Statistical Yearbook).

Coral Reefs

Photo © Shutterstock/NaniP

The Palau International Coral Reef Center (PICRC) and the Coral Reef Research Foundation (CRRF) kindly provided most of the information in this section.

State of Coral Reefs

With the exception of areas on the East Coast, shallow (3 to 10 meters) reefs in Palau are in good condition and improving. Newly addressed in this report, deeper mesophotic coral reefs (down to 150 meters), appear to be doing poorly.

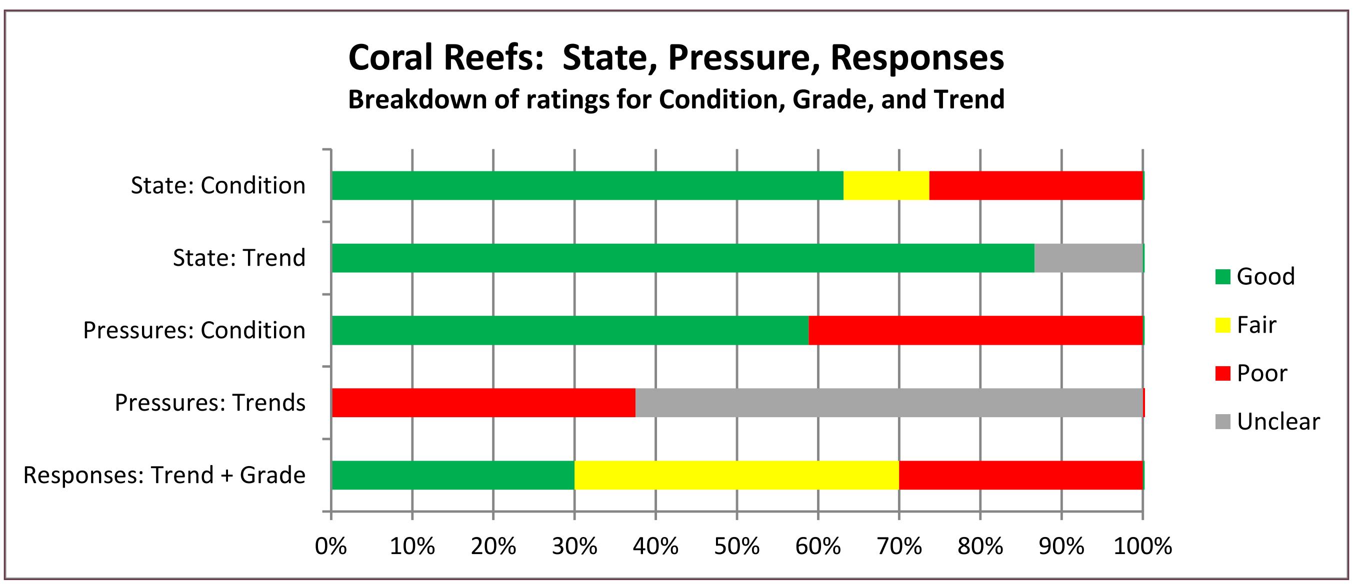
Pressures on Coral Reefs

Many of the pressures on coral reefs are intense and getting worse. Global climate change has immediate negative impacts on coral health, impacts are projected to get worse. Current and projected impacts from climate change are relatively well studied and well understood. However, local pressures (such as sedimentation onto reefs) are not as well known.

Responses for Coral Reefs

Palau has responded well to the pressures facing coral reefs, and continues to improve in its response. Continued investment in MPAs (particularly the commitment by States to set aside new MPAs), means that only lagoons and reef flats are still poorly represented in Palau's network of MPAs. Responses to local pressures have been very slow and should be improved, particularly reducing sedimentation and overfishing of reef fish.

Palau's good response to coral reef conservation and protection should now be used to imform a similar response to nearshore fisheries. Palau should maintain existing coral reef efforts, but focus new effort and attention on nearshore fisheries.



Footnotes for Indicator 1, Live Coral Cover *(See next page).*

[1] Gouezo et al. (2017).

[2] *Notes on Trend:* Trends were discussed in (Gouezo et al. 2017). Refer also to Figures I1a-d showing live coral cover over time for each location.

[3] *Basis for Condition:* The system for assigning a "Condition" (previously called "Grade" in 2017) was developed for the 2017 State of the Environment (SOE) Report, using data collected through PICRC's long-term coral reef monitoring program. Maximum coral cover within each habitat and depth was defined, based on when the coral cover asymptote and carrying capacity was reached. For western outer reefs at 10 m and inner reefs at 3 m: Very Poor (<10% cover), Poor (10%<coral cover<20%), Fair (20%<coral cover <30%), Good (30%<coral cover<50%), Very Good (> or = 50%). For all other habitats and depths, Very Poor (<8% cover), Poor (8%<coral cover<16%), Fair (16%<coral cover <24%), Good (25%<coral cover<32%), Very Good (> or = 40%).

SOE Indicator 1. Live Coral Cover

Most shallow coral reefs monitored by PICRC are in good condition. With the exception of Eastern Outer Reefs, reefs at 3 and 10 m depth have recovered well from earlier bleaching and typhoon events. Some areas of Eastern Outer Reefs, damaged by typhoons in 2012 and 2013, are recovering very slowly. Data used here went through 2016 and do not reflect Tropical Storm Lan in October 2017. At 3 and 10 m, damage from Tropical Storm Lan was limited to the west; with relatively little damage and high remaining cover, a quick recovery of shallow reefs is expected (Gouezo and Olsudong 2018; See Indicator 9). Coral cover on deeper mesophotic reefs is low, particularly below about 30 m (Colin 2019).

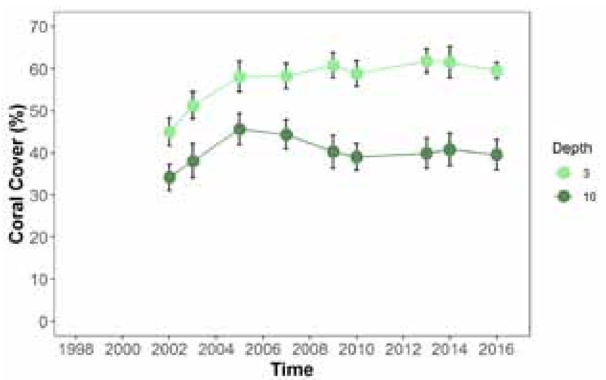
The reporting format has been changed, now assigning a "Condition" rather than "Grade." See explanatory text, left.

Inner Bay Reefs (3 and 10 m)

	State[1]	Trend[2]	Condition[3]
Depth	*% Cover*	*2002-2016*	*2016*
3 m	~60%	Stable	Very Good
10 m	~40%	Stable	Very Good

Change (2017-2019)

Asymptote present towards maximum possible coverage; the condition changed from Good to Very Good.

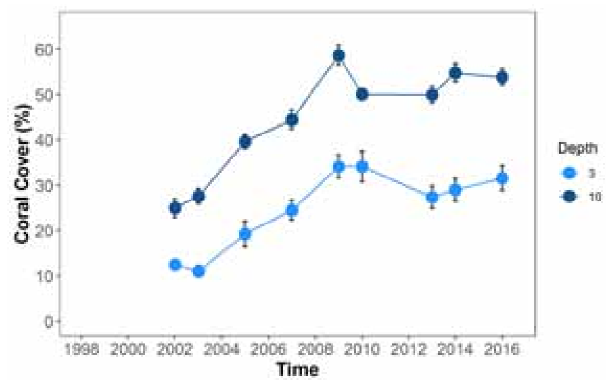


Western Outer Reefs (3 and 10 m)

	State[1]	Trend[2]	Condition[3]
Depth	*% Cover*	*2002-2016*	*2016*
3 m	~30%	Stable	Good
10 m	~50%	Stable	Very Good

Change (2017-2019)

No change.

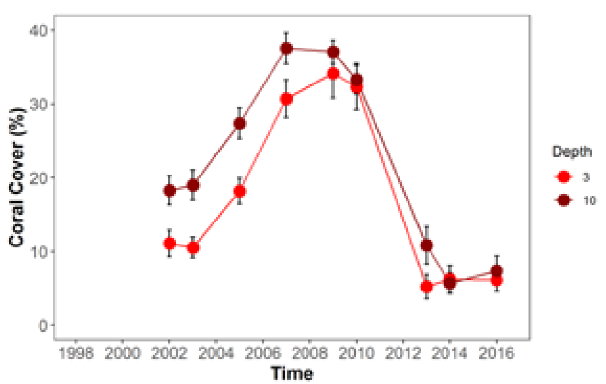


Eastern Outer Reefs (3 and 10 m)

	State[1]	Trend[2]	Condition[3]
Depth	*% Cover*	*2002-2016*	*2016*
3 m	~6%	Stable	Very Poor
10 m	~7%	Slight increase	Very Poor

Change (2017-2019)

At 10 m, reefs may show signs of recovery. Data since 2013 is insufficient to identify a clear trend.

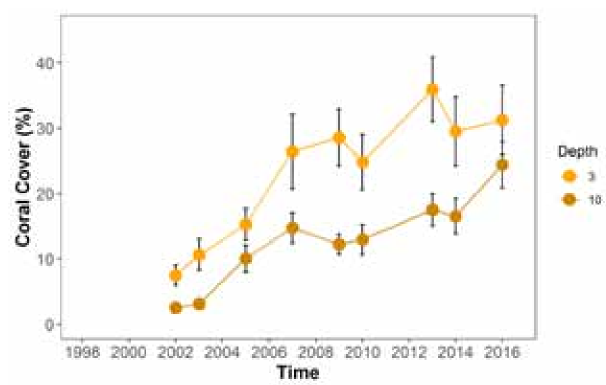


Patch Reefs (3 and 10 m)

	State[1]	Trend[2]	Condition[3]
Depth	*% Cover*	*2002-2016*	*2016*
3 m	31%	Increasing	Good
10 m	24%	Increasing	Fair

Change (2017-2019)

At 10m, cover increased from 17% to 24%, and the Condition was changed from Poor to Fair.



Figures I1a-d Live Coral Cover over time in different habitats and depths. Clockwise from top left: a) Inner Bay Reefs; b) Western Outer Reefs; c) Eastern Outer Reefs; d) Patch Reefs. All figures and data from Gouezo et al. (2017).

SOE Indicator 2. Benthic Cover (non-Coral)

This is a new indicator. The presence of Macroalgae affects coral negatively by inhibiting coral settlement, by overgrowth, and by competing with corals at different life stages (from recruits to adult colonies). In most locations macroalgal cover was low (Figure I2), but there was a small increase in macroalgae in the Inner Reefs. The increase in macroalgal cover on Inner Reefs should be closely monitored and documented. The increase could be due to natural processes, but also could be impacted by the influx of nutrients and sediment that comes with coastal development (Gouezo et al. 2017). See Figure I2.

State[1]	Trend[2]
2016	*2002-2016*
• Macroalgal cover quite low (<12%) in most locations.	Stable
• Increase in macroalgal cover on Inner Reefs (but still below 10%).	Increasing
• Rubble and sand stable in Inner and Western Outer reefs; • Increased on Eastern Outer Reefs following typhoons. • Highest in Patch Reefs (>50%).	Stable

SOE Indicator 3. Juvenile Coral Density

Juvenile Coral Density varies by location. Throughout time, trends are non-linear. The presence of juvenile coral is important to coral reef recovery, and sites recover faster if there is a high density of juvenile corals. This tends to occur where algal cover is low, rugosity is high, and substrate is available. This indicator is included both to assist in prioritizing areas for management and to provide a baseline for future changes (Gouezo et al. 2017).

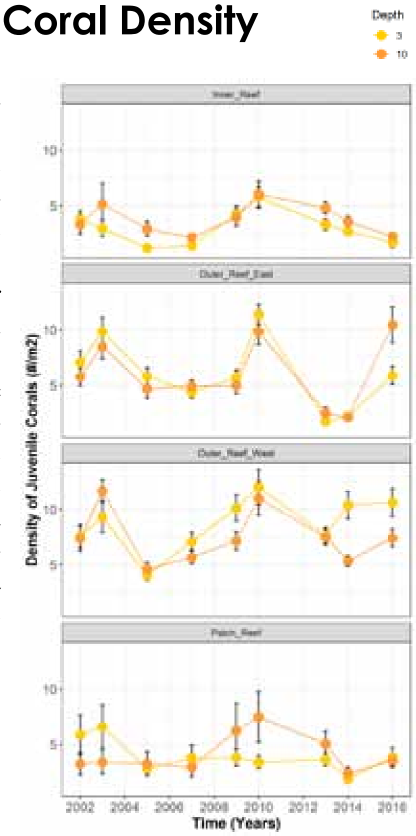
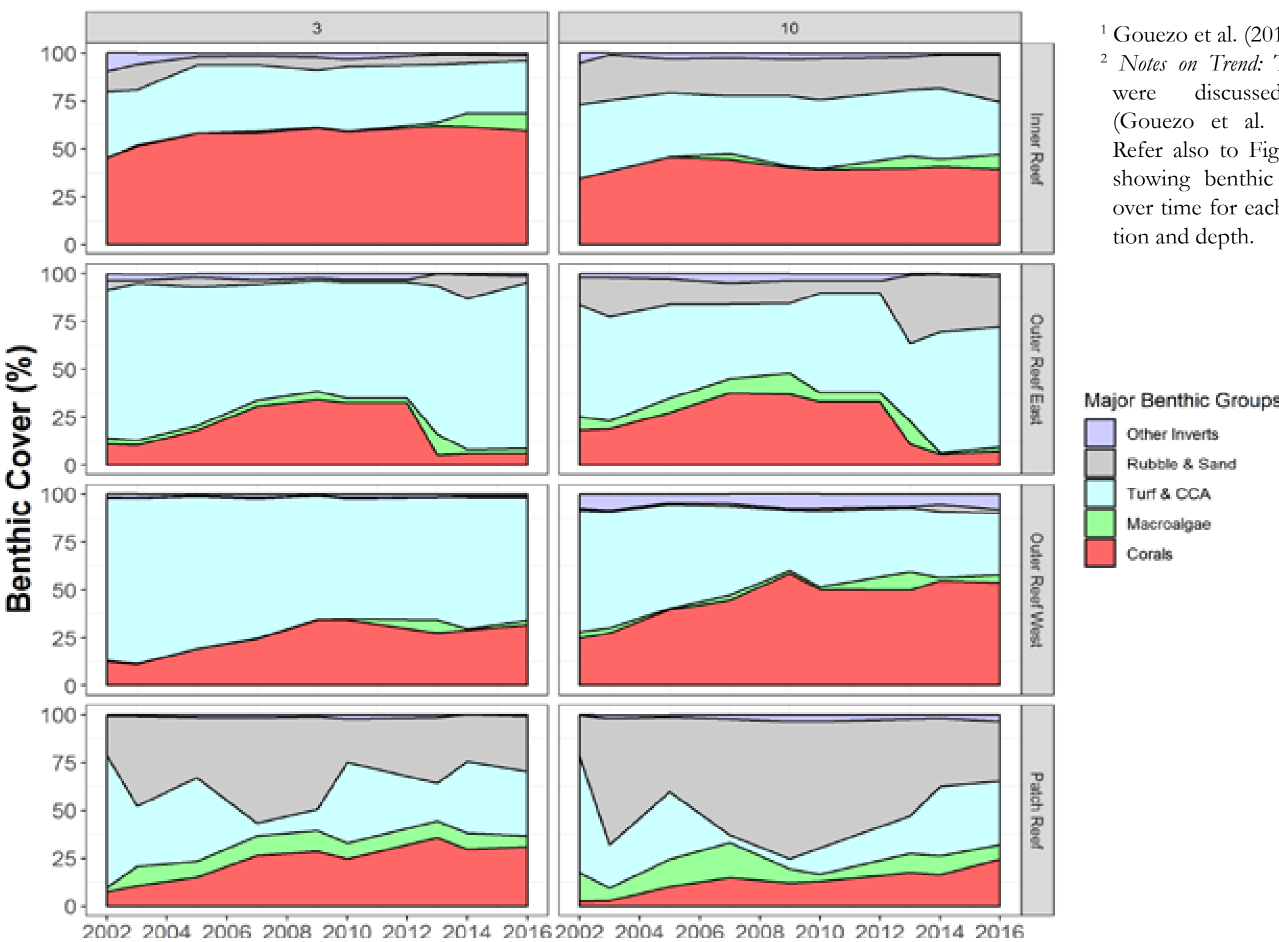


Figure I3. Juvenile coral density over time in different habitats and depths. From Gouezo et al. (2017).



[1] Gouezo et al. (2017)

[2] *Notes on Trend:* Trends were discussed in (Gouezo et al. 2017). Refer also to Figure I2 showing benthic cover over time for each location and depth.

Figure I2. Mean cover of the major benthic category trends over time in different habitats and depths. Figure from Gouezo et al. (2017).

SOE Indicator 4.
Reefs[1] with "High"[2] Coral Cover

~60% of sites had "High" Coral Cover, which is close to the defined expected pre-bleaching value (pre-1998 when 64% of sites had "High" coral cover).

Coral cover is a measure of the proportion of reef surface covered by living coral instead of other organisms or non-living elements. Coral cover is a good measure of general reef health. In general, a healthy reef has a relatively high percentage of coral cover. How a site's coral cover is defined as "High" depends on capacity, which is often estimated from historical conditions (such as here). A rapid shift away from coral domination–such as by a reduction in the extent of sites with "High" cover–can be a sign of ecosystem stress (http://www.healthyreefs.org/cms/healthy-reef-indicators/coral-cover/).

State[3]	Change	Trend[4]	Condition[5]
2016 observations	*2017-2019*	*2005-2016*	*2016*
• ~60% with "High" Cover • ~27% with "Medium" Cover	No change.	Stable	Good
• ~13% of reefs "Severely Degraded"	No change. Degraded reefs slow to recover.	Stable	Poor

[1] Of the total reefs surveyed in the main archipelago (p. 20, PICRC MAP).
[2] "High" defined as having over 50% live coral cover. "Medium" defined as 25 to 50% and "Severely Degraded" defined as less than 10% live coral cover.
[3] Gouezo, personal communication (2018).
[4] *Notes on trend:* In 2005 (post 1998 bleaching), 1 to 9% of sites had "High" coral cover (Golbuu et al. 2005). Pre-1998, 64% of sites had high coral cover (calculated from p. 10 table in Golbuu 2000).
[5] *Basis for Condition:* The current status relative to its past pre-1998 status (OceanHealthIndex.com). Comparing current to past: Very Good = Current is at least 90% of past. Good = 75-90%. Fair = 50-75%. Poor =10-50%. Very Poor = <10%. The current status, where 60% of reefs have high coral cover, is close to the pre-1998 value where 64% of reefs had high coral cover.

SOE Indicator 5.
Coral Disease

Currently coral disease is not a major problem facing Palau's reefs. No coral diseases were observed at PICRC's monitoring sites in 2014 or 2016 (Gouezo, pers. comm. 2018). Low levels of coral disease are present in several areas. Some areas have had significant infestations, particularly of Black band disease, in the past. While those areas may have recovered, other areas are now affected (Colin 2019).

Trend[1]	Condition[2]
Stable	Good

[1] *Notes on trend:* Consistent low levels of disease in the past decade.

[2] *Basis for Grade:* See 2017 SOE. Palau has few coral diseases relative to diseases on other Pacific reefs (Aeby et al. 2011).

SOE Indicator 6.
Coral Genus Diversity

Genus diversity at 3 and 10 meters increased as reefs recovered from bleaching. A trend of increasing genus diversity is newly apparent on the Eastern Outer Reefs, which are recovering from typhoons in 2012 and 2013.

State[1]	Change	Trend[2]	Condition[2]
Location	*2014-2016*	*2013-2016*	*2016*
Inner Reef	No change.	Stable	Good
Eastern Outer Reefs Genus diversity still lower than past high values	Increasing trend becoming apparent at both depths.	Increasing	Poor
Western Outer Reefs Maximum diversity (22 genera)	No change.	Increasing	Good
Patch Reefs. Lowest diversity (16 genera)	No change.	Increasing	Good
Shallow Reefs Dominated (~75%) by Porites, Acropora, and Montipora[1]	It appears that most coral communities regained their structure 10-12 years after the major bleaching events, with the exception of the Eastern Reefs.		
Mesophotic Coral Reefs [4] (40 m and deeper; steep)	Limited (>22 spp.) stony coral diversity. 52 spp. of gorgonians and soft coral. 30-40 sponges; other invertebrates include the Nautilus.		

[1] Gouezo et al. (2017).
[2] *Notes on Trend:* See Figure I6 (Gouezo et al. 2017). Genus diversity increased as reefs recovered from disturbances (1998 bleaching; 2012-2013 Typhoons). Highest recorded generic diversity recorded in time was 54 genera; no site currently has this level.
[3] *Basis for Condition:* Subjective, based on genera present compared to past high values; or presence of stability.
[4] Colin (2016b). 80% of Palau's barrier and fringing reefs have a mesophotic component.

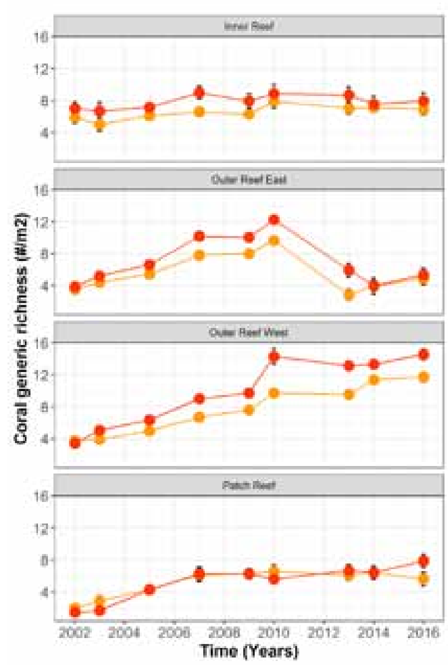


Figure I6. Mean coral genera diversity (± SE) over time in different habitats and depths. Figure from Gouezo et al. (2017).

Overview of Pressures on Coral Reefs

Four (4) primary pressures and threats to coral reefs area addressed here, based on threats identified in the 2017 SOE.

Climate Change
(Daily cumulative plus long-term impacts)
Indicators 7-11

Overfishing
Indicator 12
See also Indicators 16-29 & 34

Sedimentation from land
Indicator 13

Damage from visitation
(e.g. from snorkelers or boats)
Indicator 14

Climate Change Pressures: Temperature and Bleaching

SOE Indicator 7. Variability and rise in ocean water temperature

2019 Temperature

In March 2019 both shallow and deeper waters had some of the coolest water measured since 1999. Shallow areas (~2-25 m deep) were well below 28° C, with daily means often around 27.5°C. See the section on Bleaching; although in March 2019 no bleaching was predicted, conditions can shift dramatically from El Niño to La Niña in just a few months (Colin 2019).

Long-term Temperature Change

Water temperatures throughout Palau have been monitored closely by CRRF since 1999 (Colin 2019). The patterns of ocean water temperature at various depths since 1999 is shown in Figure I7a. Shallow reef areas have comparatively stable temperatures, usually in the range of 28-30° C. However, near the lower limits of reef growth in Palau (at about 60 m depth) the variation over months to years in temperature is vastly greater, with a range of about 21 to 29° C. Just below the true reef depths, at 90 m deep, temperatures dip into the mid-teens for weeks to months, the lowest temperature ever having been recorded at that depth in Palau was 8.6° C back in 1999 (Colin 2019).

Figure I7a shows a simple straight line regression for weekly mean water temperatures since 1999 at three depths (15, 57, and 90 m). These all indicate an upward trend in temperatures of about 0.03° C per year (or 0.3° C per decade, also see Colin 2018). This indication is consistent with the generalized world increases in water temperature and show that Palau is no exception to what is happening in the overall ocean. The trends for deeper depths (57 and 90 m) are less certain, as the day to day and year to year variation is much higher, hence these short term variations tend to overwhelm the longer term when looking at a graphic presentation of the data (Colin 2019).

There have been significant increases in sea surface temperatures over the 20th Century in Palau (van Woesik et al. 2015; Figure I7b). Projections for all emissions scenarios indicate that the annual average sea surface temperature will

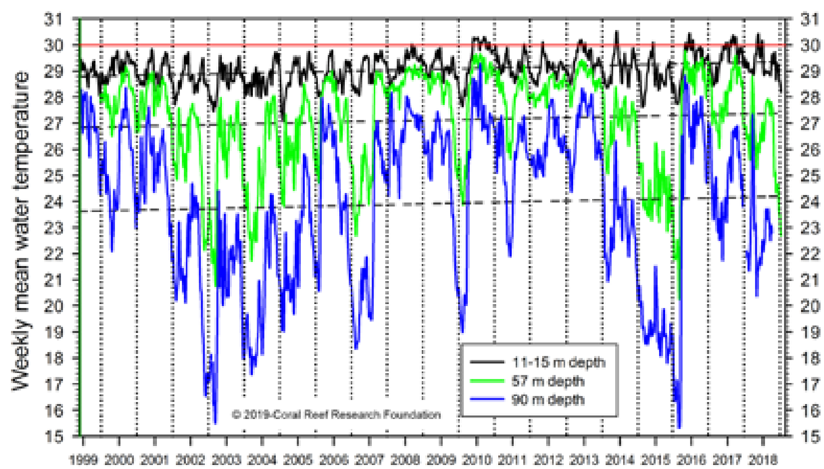


Figure I7a. Weekly mean water temperatures at various depths on the outer slope of Palau, 1999-2018. Deeper depths (57 and 90 m) have highly variable temperatures over both short periods (min. to hours) and longer periods (weeks to months and years). The recognition of this variation and the occurrence of high temperatures to the deepest depths of reefs has been a major discovery from this work by CRRF. Figure from Colin (2019).

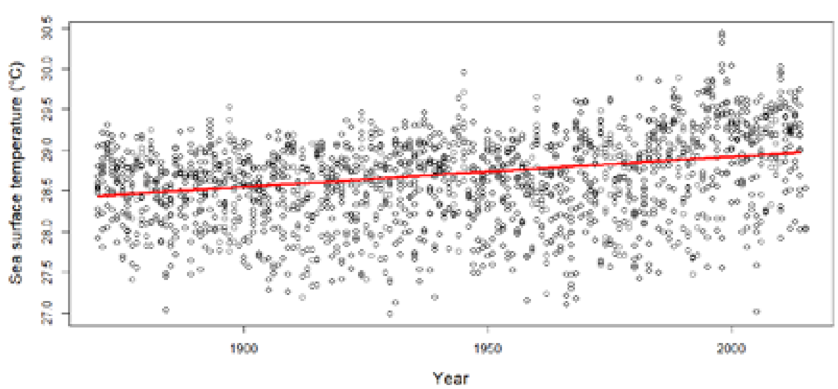


Figure I7b. Regression plot of sea surface temperature for Palau dating back from 1870 through to March 2015. The slope of the regression, or the rate of change in temperature, was estimated at 0.0037° C per year. From Figure S2 in Van Woesik et al. (2015).

	State[1]	Trend[1]
Depth	*1999-2018*	
15 m	0.03° C /yr (0.3° C / decade)	Clearly Increasing
57 m		Increasing, Variable
90 m		Increasing, Variable

[1] Colin (2019)

Understanding variability in ocean temperatures

This information was kindly provided by CRRF.

The temperature of the ocean and lagoon around Palau is one of the most critical environmental parameters to track.

Water temperature is influenced by global conditions (such as warming), global climate shifts, local short term weather shifts, and major storm events (such as typhoons). With so many factors operating at once, determining trends in temperature data is difficult due to large variation in most of these factors over multiple time scales.

Water temperature is very important for the health of the shallow water marine environments of Palau, both within the broad lagoons and along the outer steep slope facing the deep ocean. The cycles of El Niño and La Niña, collectively the El Niño Southern Oscillation (ENSO), are evident in ocean water temperatures, with high temperatures occurring during La Niña and lower temperatures during El Niño periods. The La Niña high temperatures can induce coral bleaching–loss of the symbiotic algae found in corals–resulting in coral death at all depths where coral reefs occur and shifts in dominant organisms in communities in shallow areas. El Niño low water temperatures are generally good for most reefs in Palau, however the areas with deeper reefs– below about 45 m (150 feet)–may become so cool that coral there undergo a poorly known phenomenon known as "cold water bleaching". El Niño can also induce phytoplankton blooms in the open ocean at depths of 40-60 m (Colin 2016a; Colin 2018) which is important for both oceanic fisheries production and coral reef nutrition.

The mesophotic reef zone of Palau, from roughly 30 m (100 feet) depth to the bottom of the photic zone about 100 m (330 feet) is the most thermally dynamic region in the tropical ocean. Temperature can change several degrees C in minutes, due to internal waves along thermoclines between layers of water, but also over weeks to months due to ENSO conditions. Ocean water temperature also has a close relationship with mean sea level (Indicator 8), higher water temperatures (La Niña) occurring with higher mean sea levels, and low temperatures (El Niño) associated with low mean sea levels (Schramek et al. 2018; Colin 2018).

continue to increase. By 2030, under a very high emissions scenario, this increase is projected to be 0.6-1.0°C (PACCSAP 2015). Sea surface temperatures are expected to rise by 1.0-2.0°C by 2050 and 2.0-4.0° by 2090 (TNC 2015).

Bleaching

In shallow water when temperatures exceed 30° C for days to weeks, coral bleaching can occur.[1] Temperatures have climbed above this level a number of times since 2010, the last bleaching event of significance (Figure I7a). Most of these excursions were short and did not produce significant bleaching, with these occurrences in 2017-2018 (Figure I7c) being followed by decreases that defused the imminent bleaching. During most of 2017-2018 the ENSO conditions were "neutral", meaning it was neither in El Niño or La Niña. At the end of 2018 water temperatures started decreasing again, similar to the 2015 El Niño

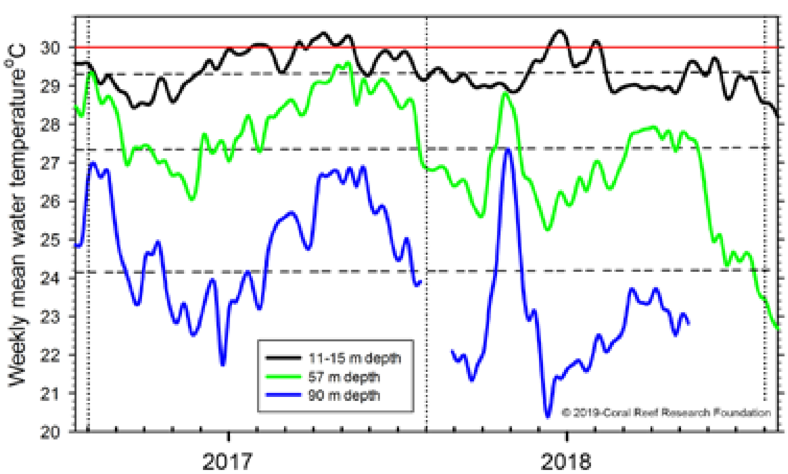


Figure I7c. The two year trends of weekly water temperature show how at times the water column is nearly the same temperature from the surface to 90 m depth (March-April 2018) and can quickly switch to highly stratified temperatures (May 2018). The past two years (2017-2018) have had only short periods of near surface temperatures above the nominal 30° C coral bleaching threshold. Such short excursions above that level do not usually induce bleaching unless they persist for some weeks. Figure from Colin (2019).

drop (Figure I7a), coupled with a significant lowering of mean sea level (Indicator 8) which accompanies El Niño in Palau (Colin 2019). Highly variable water temperatures at the deepest depths of reefs in Palau have caused both warm-water and cold-water coral bleaching (Colin and Lindfield 2019).

On average reefs took 9 to 12 years to recover after the massive 1998 bleaching event (Gouezo et al. 2019). Inner reefs either were less impacted by the 1998 bleaching or recovered faster, whereas outer reefs reached their carrying capacity around 2009. Patch reefs were heavily impacted by 1998 bleaching and it is unsure if they are fully recovered (see Indicator 1) (Gouezo 2017).

Globally, one quarter of reefs are expected to bleach annually by 2040 (van Hooidonk et al. 2013). No bleaching trend was indicated for Palau in early 2019 (Figure I7d; NOAA 2019, SPC 2019).

[1] Nikko Bay has a temperature above 30° C almost year round, because of poor flushing, yet areas seem to be resilient to bleaching (Yuen et al. 2018).

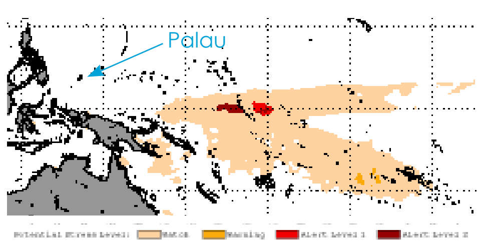


Figure I7d. 4-week coral bleaching outlook for Palau (Coral Reef Watch, 03/07/2019). Figure modified from NOAA (2019).

Climate Change Pressures: Changing Sea Level, Tides

SOE Indicator 8. Sea Level Rise

Palau has semidiurnal tides with a maximum range of about 2.3 m on a single tidal cycle. Most ranges are considerably less, with the average range about 1.6 to 1.7 m. Global sea level is rising at about 3 mm a year, from both overall warming of the oceans (warmer water expands) and melting of ice sheets held on land. Looking at sea level in Palau since 1969, the first year reliable tide gauge records are available, sea level has increased a bit less, roughly 2 mm a year. This does not mean that Palau has the sea rising faster or slower than world averages, rather it is a product of sea level variation month to month at a single location calculated from decades of data with tens of thousands of measurements. During the 2017-2018 period, sea level was lower than average, and there have been no reports of damage to taro patches or other coastal environments from rising tides during that time (Colin 2019).

It is certain, like the rest of the world, that Palau's sea level is *rising at the global rate when yearly rates are considered.* Short term variation (days to months) has much greater variability, and temporary changes of as much as 650 mm in mean sea level can occur in just a few months (Colin 2019).

The University of Hawaii Sea Level Center (UHSLC) produced valuable global maps showing trends in sea level over both the last 10 and 20 years and since 1993, with versions which show trends if general sea level rise is included or ignored (Colin 2019). Since 1993, sea level in Palau has increased by approximately 9 mm/yr (Figure I8a from UHSLC 2019; 9 mm value from PACSAP 2015). Looking back further, analysis of daily tidal data (1969-2014) showed an increase in sea level of 2.87 mm/yr, consistent with the regional Pacific average rise of ~2.7 mm/yr and higher than the global average of ~1.8 mm/yr (1970–2008) (van Woesik et al. 2015). However, there is variability depending on the time scale. For instance, sea level in Palau has gone down about 8-10 mm per year if only the ten years up to 2017 are considered (Figure I8b) (Colin 2019).

By 2030, under a very high emissions scenario, sea level rise is projected to be in the range of 80-180 mm (PACSAP 2015).

van Woesik et al. (2015) found that Porites microatolls from reef flats in Palau are able to grow vertically at pace with a 3 mm/year sea level rise. However, sea level drops that occur at ~5-year intervals from El Niño can lead to mortality of these corals (Colin 2016a). Identifying resilient corals and minimizing local stressors are priorities of the PAN.

Timeframe	State	Trend
1969-2014	2[1] to 2.9[2] mm/yr	Increasing
1993-2017	9[3] mm/yr	Increasing
2008-2017	-8 to -10 mm/yr[1]	Decreasing

[1] Colin (2019) [2] van Woesik et al. (2015) [3] PACSAP (2015)

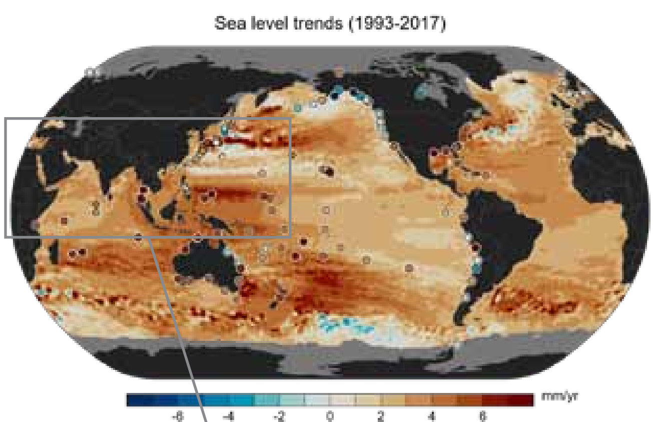


Figure I8a. Global and local sea level trends since 1993.

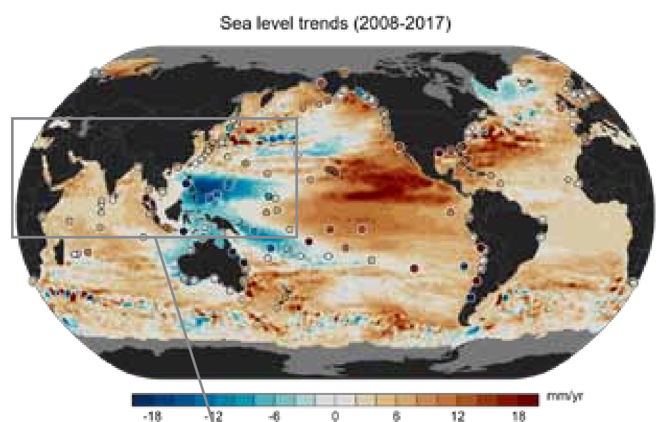
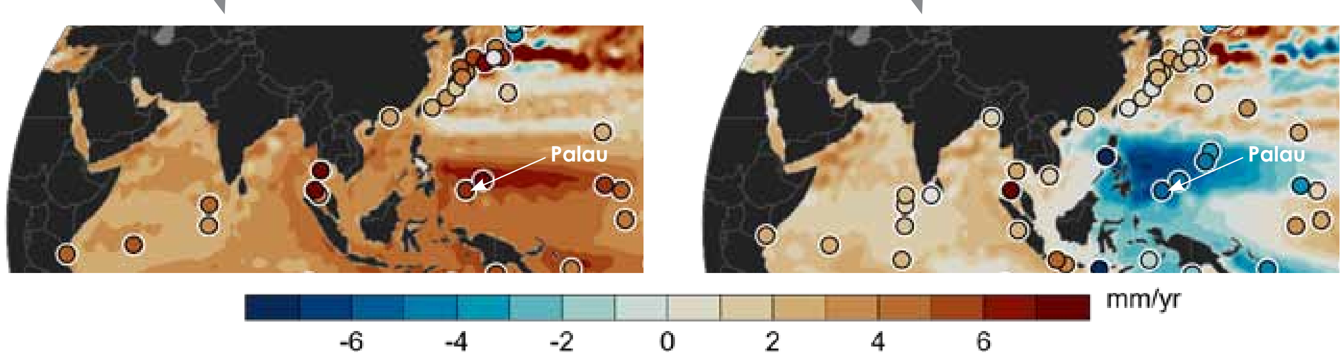


Figure I8b. Global and local sea level trends for the ten years from 2008 to 2017.



Images from the University of Hawaii Sea Level Center (UHSCL, as of 2/26/2019, https://uhslc.soest.hawaii.edu/): "Trends were calculated using (1) tide gauge data from the UHSLC Fast-Delivery database, and (2) Ssalto/Duacs altimeter products that were produced and distributed by the E.U. Copernicus Marine and Environment Monitoring Service (CMEMS). The latter are identical to the products formerly distributed by Aviso."

Climate Change Pressures: Stronger Typhoons and Storms

SOE Indicator 9. Damage to coral from typhoons and tropical storms

Damage by Depth

Typhoons and Tropical Storms can cause significant damage to coral reefs (Figure I9a-b), varying by site and depth. Some shallow reefs (3 to 10 m deep) have had near complete loss of live coral (see Table).

Mesophotic reefs (30-150 m deep) appear to have deteriorated in the past 20 years, largely due to the effects of storms causing massive amount of rubble to move downslope, combined with sedimentation from those storms (Colin 2016b).

Recovery

Recovery varies by site and depth. At PICRC's monitoring sites, total coral cover has decreased 5-6% since Typhoons Bopha and Haiyan, and remains low (Indicator 1). Some Eastern sites (like Lighthouse Reef, which had very low coral cover following Typhoon Bopha) have had notable recovery (see 3-4 year old Acropora Table Coral in Figure I9c). Identifying and protecting resilient reefs remains a priority of the PAN.

Storm Frequency

20 typhoon-strength storms passed within 200 nautical miles of Palau between 1945 and 2013, averaging 1 typhoon every 3 years (CRRF 2014). The closest point was most often Kayangel. Predictions are not clear on the expected future frequency of typhoons. However, typhoons that do occur are predicted to be of higher intensity, with an increase in wind speed of 2-11% and an increase in rainfall intensity of ~20% (PACCSAP 2015).

	State (change in Live Coral Cover)							
Storm	*Inner Reef*		*Eastern Outer Reef*		*Western Outer Reef*		*Patch Reef*	
	3 m	*10 m*	*3 m*	*10 m*	*3 m*	*10 m*	*3 m*	*10 m*
Typhoon Bopha, 2012 *(PICRC survey 1 month after)*[1]	No change 51 to 49%	No change 32 to 33%	Decrease 30 to 5%	Decrease 32 to 11%	Decrease 34 to 27%	Decrease 56 to 50%	Increase 29 to 43%	Increase 14 to 20%
Typhoon Haiyan, 2013 *(PICRC survey 6 months after)*[1]	No change	No change 33 to 32%	No change 5 to 6%	Decrease 11 to 6%	No change 27 to 29%	Increase 50 to 55%	Decrease 43 to 35%	No change 20 to 21%
Tropical Storm Lan, 2017[2]	*Western Outer Reef* • Decrease. *3 m*: 34 to 19%; *10 m*: 50 to 41%. Greatest impact at Ngemelis (See Figure I9b).[2] • Heavy damage in limited areas on western barrier reef, including at deeper depths (Figure I9d).[3] • Filamentous green algae bloom occurred ~10 days after Tropical Storm Lan, and persisted for ~6 weeks (Figure I9e).[4]							

[1] Gouezo et al. (2015)
[2] Gouezo and Olsudong (2017). PICRC surveys were 2-3 weeks after.
[3] Colin, pers. comm. (2019).
[4] Similar blooms occurred elsewhere after Typhoons Bopha and Haiyan. Blooms have not been documented before, and are included here as baseline. Colin, pers. comm. (2019).

Figure I9a. Western Outer Reef north of Ulong Channel, before (*top*) and after (*bottom*) Tropical Storm Lan. Copyright CRRF 2019.

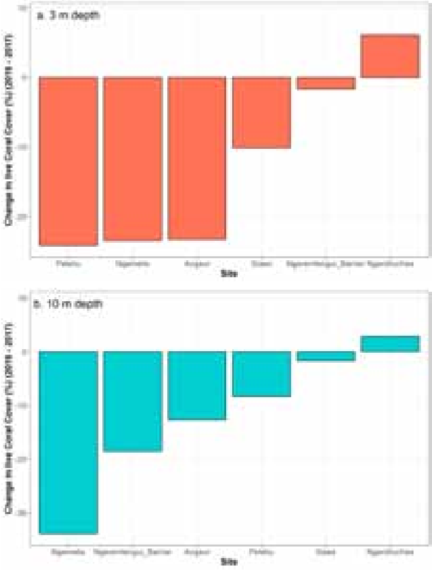


Figure I9b. Figure I9b. Barplot showing the mean absolute change in coral cover at individual sites at a) 3m (*top*) and b) 10m (*bottom*) depth after Tropical Storm Lan. Figure from Gouezo and Olsudong (2017).

Figure I9c. 3 m deep at Lighthouse Reef in 2018, showing recovery of tabulate *Acropora* after Typhoon Bopha. Copyright CRRF 2019.

Figure I9d (*left*). Damage on the Western Outer Reef at 12-15 m following Tropical Storm Lan in 2017. Copyright CRRF 2019.

Figure I9e. Aerial view and underwater view (*inset*) showing filamentous algae bloom following Tropical Storm Lan in 2017. Copyright CRRF 2019.

Climate Change Pressures: Ocean Acidification

SDG 14.3.1

SOE Indicator 10. Marine Acidity

Data show that since the 18th century the level of ocean acidification has been slowly increasing in Palau's waters (PACCSAP 2015). Over the last two centuries in Palau, the aragonite saturation state (a proxy for coral reef growth rate) has declined from 4.5 to 3.9 (TNC 2015). Acidity levels of sea waters in the Palau region will continue to increase over the 21st century (PACCSAP 2015). Models suggest that the aragonite saturation rate will continue to decrease to 3.5 (which is the marginal condition to support coral reefs) by 2030 and decrease further to values where coral reefs have not historically been found (< 3.0) (TNC 2015).

State		**Trend[3]**
2006[1]	*2015[2]*	*2006-2015*
• pH (all sites) average = 8.13	• pH (outer reef) = 8.04 • pH (Rock Islands) = 7.84	Increasing Acidity (Decreasing pH)

[1] Calculated from EQPB monthly data in Marino et al. (2008). [2] Barkley et al. (2015).
[3] *Notes on Trend*: Increasing acidity decreases the viability of coral reefs. Given Palau's dependence on coral reefs for fisheries and tourism, this is defined here as an undesirable trend.

Climate Change Pressures: Increasing Rainfall, Extreme weather

SOE Indicator 11. Rainfall Variability

Sedimentation from land, which is higher following intense or high rainfall, especially after droughts, puts pressure on reefs.

Total annual rainfall appears to have increased by ~3 inches (76mm) between 1948 and 2011 (TNC 2015). Confirming the trend is difficult, because the data is very variable (Figure I11a). Rainfall variability increased over the long-term (Figure I11b). Rainfall during the wet season is projected to increase: 2% by 2030; ~4% by 2050; and ~8% by 2090, especially in the wet season (PACCSAP 2015). Projections show extreme rainfall days are likely to occur more often and be more intense (PACCSAP 2015). However, the number of months with higher-than-average rainfall (defined here as 50% or more rainfall than the monthly average) has decreased (Figure I11c). Climate variables are monitored by NOAA, the Palau Weather Service, and CRRF.

State[1]		**Trend**
1970-1972	*2014-2016*	*1901-2016*
Average monthly deviation from yearly average • 1970 = 28% • 1971 = 21% • 1972 = 30%	Average monthly deviation from yearly average • 2014 = 36% • 2015 = 36% • 2016 = 41%	Increasing Variability

[1] Calculated from Historical Monthly Rainfall Data 1901-2015 (The World Bank Climate Change Knowledge Portal). 2016 monthly rainfall from BBP (2019d).

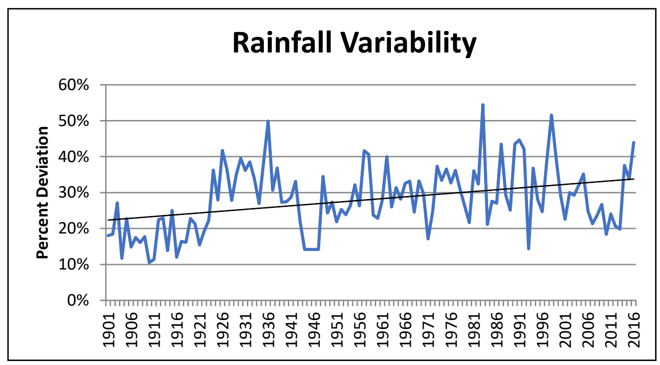


Figure I11b. The percent by which each individual month's total rainfall deviates from that year's 12-month average.

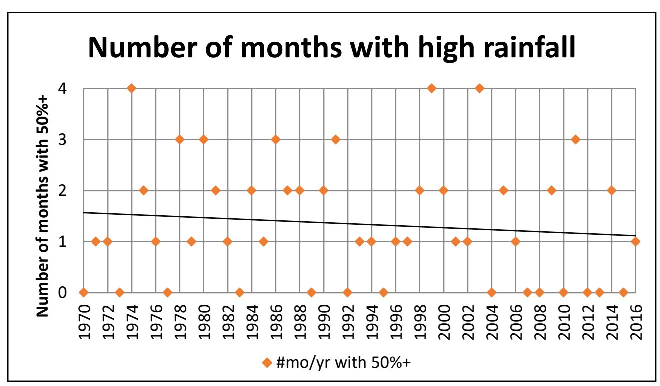


Figure I11c. Orange dots indicate the number of months in that year with higher-than-average rainfall. This graph compares monthly totals to the monthly average (e.g. each January total is compared to the January 1970-2016 average), and shows the number of months per year where the monthly total was 50% or greater than the average monthly rainfall.

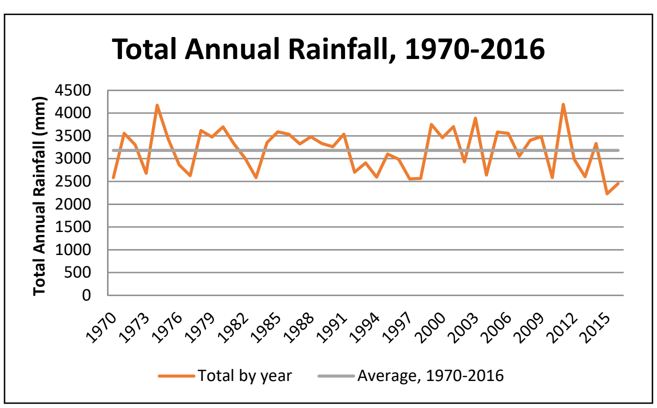


Figure I11a. Rainfall totals by year, with the average annual rainfall

SOE Indicator 12. Overfishing of herbivores from reefs

Overfishing from coral reefs is not monitored directly; see Indicators 16-17 and 22-25 on reef fish. Roff et al. (2018) noted that "Notionally herbivorous fishes maintain a critical ecosystem function on coral reefs by grazing algae and maintaining highly productive algal turf assemblages" and "Coral cover and total grazeable cover have previously been correlated with herbivore biomass." However, Roff et al. (2018) also found that much about the Herbivore-Reef relationship is unknown and unpredictable.

Bejarano et al. (2013) found ecological concerns associated with heavy exploitation of six species of herbivores, most notably *Naso Unicornis* (Chum), which has a "non-redundant" (e.g. unique) role as a macroalgal browser. Table I14 lists these six species, their ecological role on coral reefs, and the percent of catch that was immature (a measure of overfishing) in 2009.

Roff et al. (2018) described the herbivore fishery as "lightly exploited" and "herbivore densities are still regionally high." Overfishing may be limited to certain locations.

Table I12. Six heavily exploited herbivorous fishes in 2009 and their ecological role (Bejarano et al. 2013).

Species Name	Palauan Name	English Name	Ecological Role	% immature
Naso unicornis	Chum (Um)	Bluespine unicornfish	Macroalgal browser	40%
Hipposcarus longiceps	Ngyaoch/Berkism	Pacific longnose parrotfish	Scaper/Small excavator	26%
Siganus punctatus	Klsebuul	Goldspotted rabbitfish	Grazer/Detritivore	9%
Cetoscarus bicolor	Beyadel/Ngesngis	Spotted parrotfish	Large excavator/Bioeroder	21%
Scarus ruboviolaceus	Butiliang	Redlip parrotfish	Scaper/Small excavator	34%
Chlorurus microrhinos	Otord	Steephead parrotfish	Large excavator	30%

SOE Indicator 13.

Sedimentation onto Reefs

Although sedimentation onto reefs is considered one of the main pressures on coral reefs, it is not monitored and there is very little quantitative information on sedimentation.

The 2017 State of the Environment Report reported that the Siltation Rate on Babeldaob (Ngerikiil and Ngerdorch) increased between 2003 and 2011, but there are no new similar studies available to update the trend.

On Babeldaob, Golbuu et al. (2011) found that reef sedimentation rate and reef turbidity increased strongly with increasing numbers of earthmoving permits, concluding that "land-based development activities have a direct impact on the amount of sediment that goes into rivers and eventually ends up on coral reefs. The amount of sediments being released into the rivers and reefs on Babeldaob Island, Palau, depended on the degree of development within adjacent watersheds."

The number of Earthmoving permits issued continues to increase, with most apparently on Babeldaob (Figure I13). 2018 had the highest number of earthmoving permits issued since at least 2007 (316; see Indicator 88). Babeldaob soils are highly erodable, and even permitted development projects have been known to contribute to sedimentation onto reefs.

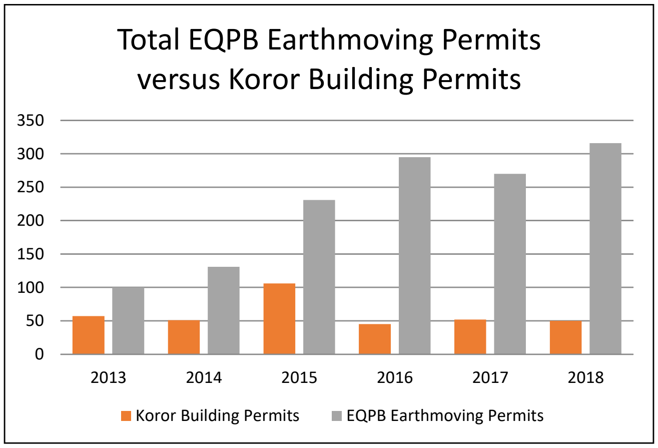


Figure I13. It appears that much of Palau's development is largely outside Koror. When on Babeldaob, sedimentation is possible.

The threat of sedimentation also increases with increasing rainfall and/or more intense rain events (see Indicator 11).

Soils and topography outside of Babeldaob are very different from those found there. Earthmoving permits do not necessarily lead to sedimentation in these areas (e.g. Koror).

Whether sediment damages coral also varies with location.

SOE Indicator 14. Damage from Visitation

PICRC Researchers found that density of coral fragments was higher at visited sites in the Rock Islands than non-visited sites (Figure I14; Nestor et al. 2017, Otto et al. 2016). Visitors were observed kicking, standing, and touching the reef, plus feeding fish. Nestor et al. (2017) concluded that snorkelers had low overall impact on coral cover, which remained high. However, this type of damage can be chronic and add up. Wabnitz et al. (2017) recommended reducing diver numbers per site and year to 5000-7000, noting that the threshold was currently being exceeded by a factor of 13. Poonian et al. (2010) estimated 50,000 dives/year at German Channel. Diver impact is thought to be less than that of snorkelers.

State	Condition
Visitation rates far exceed recommended	Poor

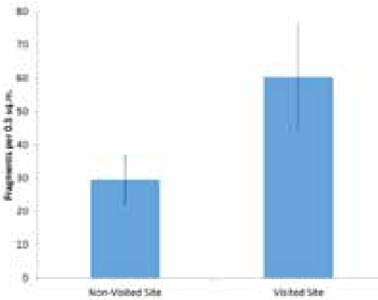


Figure I14. Density of coral fragments at visited and non-visited sites in the Rock Islands. Figure from Nester et al. (2017).

SDG 14.5.1

SOE Indicator 15. Percentage of Reef in No-Take MPAs

This indicator only considers coral reefs that are protected in No-Take zones (IUCN Categories I to IV); see Indicator 37 for all MPAs. Specific levels of protection by habitat are compared to The Nature Conservancy's Ecoregional Assessment Thresholds (TNC ERA 2007), which determined the minimum amount of reef (by type) that needs to be protected to maintain ecological viability. Thus, the total amount protected is not compared here to the Convention of Biological Diversity's (CBD) Aichi Biodiversity Target 11 (Conservation of 10% of coastal and marine areas) or the Micronesia Challenge (MC, Effective Conservation of 30% of nearshore marine environment); see Indicator 37.

	State		**Change[2]**	**Trend**
Type	*2017[1]*	*2019[2]*		*2017-2019*
Protected Reefs	14.0%	19.6%	• Expansion of Olterukl and Iuul • Designation of Olterukl, Iuul, and Ngkesol-Ngerael as No-Take	Increasing
Protected Reefs in the Palau PAN	11.2%	16.8%	• Expansion of the PAN to include Ngerchebal, plus the expanded and new areas of Olterukl, Iuul, and Ngkesol-Ngerael	Increasing

		Change	**State (and Grade[4])**	
Reef habitat	*ERA Threshold[3]*	*Change[2]*	*% of habitat in No-Take MPAs (2017 SOE)[2]*	*% of habitat in No-Take MPAs (2019)[2]*
Outer Reef	40%	Designation of Ngkesol-Ngerael as no-take	25.7% (Fair; 64% to ERA threshold)	46.3% (Good; 115% to ERA threshold)
Channel Habitat	50-60% (55% used for Grade calculations)	Designation of Ngkesol-Ngerael as no-take	29.41% (Fair; 53% to ERA threshold)	29.42% (Fair; 53% to ERA threshold)
Back Reef	40%	Designation of Ngkesol-Ngerael as no-take	16.8% (Poor; 42% to ERA threshold)	22.7% (Fair; 56% to ERA threshold)
Lagoon and Reef Flats	40%	Expansion of Olterukl and Iuul, and designation as no-take	9.1% (Poor; 23% to ERA threshold)	13.3% (Poor; 33% to ERA threshold)

[1] Data from the 2017 State of Environment (SOE) was taken from Gouezo et al. (2016).

[2] New MPAs containing reef were identified by PCS and TNC in response to requests for information. TNC Palau provided area data (2019, unpublished) that was used to update the table in Gouezo et al. (2016) and calculate new percentages. Unlike in Gouezo et al. (2016), lagoon and reef flats were combined in order to compare against available TNC ERA Thresholds.

[3] Following the 2017 SOE, this report uses The Nature Conservancy's Ecoregional Assessment (TNC ERA 2007) as the basis for protection thresholds. Recommended protection thresholds in the TNC ERA are specific to habitat types and consider ecosystem uniqueness and viability. The TNC ERA (2007) thresholds are notably higher than the Micronesia Challenge goal of "Effectively Conserving" 30% of Palau's nearshore marine environment. The 30% goal is based on both environmental and social conditions and considers Palau's marine environment as a whole, without breaking out individual habitats.

[4] *Basis for Grade:* Comparing current to desired, based on protection thresholds to ensure the long-term viability of the conservation target, in TNC ERA (2007). Good = Current is at least 75% of threshold. Fair = 50-75%. Poor =<50%.

Photo courtesy of PCS

Overview of Responses and Gaps to Primary Pressures

Palau's coral reefs are generally in good condition, and trends are overwhelmingly positive (healthy/desirable). Of the 15 unique indicators (across habitat, depth, and location) assessed for Condition, 67% were Good. Of the 18 unique indicators with adequate information to see a trend, 83% showed positive trends.

Coral reefs are by far the most understood and best managed of Palau's natural resources, and have been the focus of significant investment by local, nonprofit, and international entities for several decades. Although gaps exist, they reflect evolving management, not lack of management.

Palau should maintain existing programs to manage coral reefs, but also continue the ongoing process to decentralize coral reef management to States and communities (with access to central resources via the National Government and nonprofits). This SOE recommends that Palau should now take the successes it has seen in coral reef management, and apply that knowledge to nearshore fisheries management.

Primary Pressure	Primary Responses	Key Gaps
Climate Change	• MPAs (particularly resilient areas) • Investment in management via PAN and by other funding sources (grants, partnerships) • Significant, extensive, and comprehensive Research and Monitoring, by local, regional, and international entities (academia, nonprofit, semi-government, and government).	• Few MPAs that protect Channels, Back Reef, and Reef Flats (see Indicator 15) • Less understanding of mesophotic reefs (deeper water corals) • Spatial maps of resilient reefs vis-à-vis connectivity levels or thermal tolerance (PICRC work is ongoing) • Methods for large-scale coral restoration
Overfishing on Reefs	• MPAs, plus training and PAN funding • Regulations on Size limits, Seasonal and Species Closures, Gear restrictions • PNMS (and shift towards tuna consumption) • Investment in Aquaculture (especially clams) • Implementation of Sustainable Tourism Framework • Coops and Sustainable Fisheries Partnerships	• No regulations or targets for overall catch • Inadequate size or other regulations (Indicators 35-36) • Little fisheries monitoring • Continued export of nearshore fish and invertebrates (on passenger aircraft)
Sedimentation	• Landscape Planning and Land Use Planning • Terrestrial Conservation Areas • Best Practices in Agriculture • Implementation of EQPB Regulations for Earthmoving (e.g. Permit conditions)	• Number and extent of land use plans increasing very slowly; no quotas or limits on development or earthmoving • Little monitoring of Sedimentation • Low funding and staff at EQPB to monitor and enforce Permit conditions
Damage from Visitation	• Tour Guide Training • Palau Pledge and educational outreach • Fees, fines, permits, and enforcement • Zoning and MPAs • Implementation of Sustainable Tourism Policy	• Few limits on visitation (e.g. number of visitors allowed or regulated avoidance during low tide) • No regular monitoring

Addressing Pressures, Risks, and Gaps reported in the 2017 SOE

The 2017 SOE called for additional protections for reefs. Now nearly 20% of Palau's reefs are No-Take MPAs.

The 2017 SOE listed these as needs: reduced reef fishing, land use planning, erosion control measures, improved enforcement of MPAs, and some reef rehabilitation. Some effort has been put into reducing reef fishing. Lower consumption (by shifting to tuna) is now encouraged through the PNMS and Sustainable Tourism Framework.

Significant effort has been put into land use planning by individual States, NGOs, and via the GEF5 project. In 2018 Palau also started the 6-year GEF6 project on island- and lagoon-wide landscape, seascape, and land use planning.

A wealth of up-to-date information–including technical reports and data–is available publicly on the CRRF and PICRC websites.

Correction and Update

The 2017 SOE did not accurately portray available bathymetry, and incorrectly suggested that bathymetric data is limited to project-based data at one institution. Highly detailed SHOAL program charts (Airborne LIDAR surveys) of all harbors, channels, and reef areas were done in 2004 and published afterwards (Colin 2019). See the following section on Research and Monitoring of Marine Areas for more detail. Various other bathymetric data sets for Palau can be found at https://maps.ngdc.noaa.gov/viewers/bathymetry/.

Marine research and monitoring in Palau

Palau is fortunate to have two world class research institutions based in Palau, who conduct innovative research and implement comprehensive, regular monitoring programs. Local and international nonprofits also contribute to the body of research and monitoring data available for Palau's marine environments. The vast majority of funding to support these efforts comes from external courses (e.g. grants, contracts, and donations).

Palau International Coral Reef Center (PICRC)

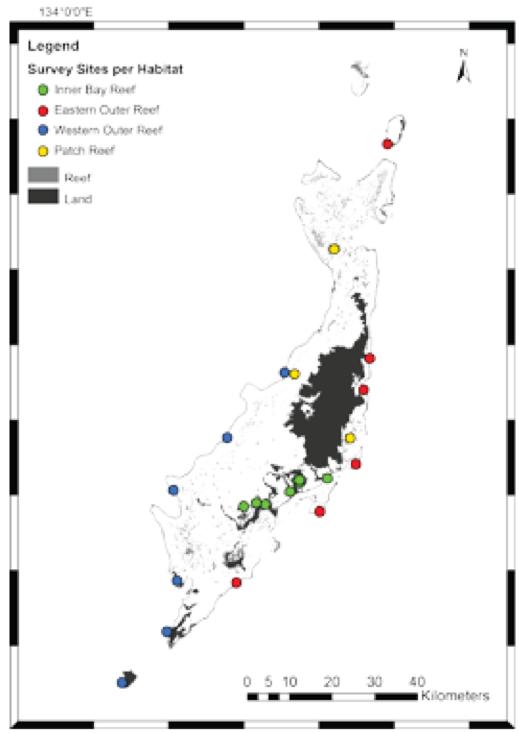
The Palau International Coral Reef Center (PICRC) conducts regular monitoring of Palau's reefs, fisheries, MPAs, and other natural resources (Table 1 and Map, right).

PICRC's research is designed to guide stewardship of reef resources. This includes fisheries research on specific species of interest (groupers, parrotfish, wrasses) and on land-based practices to minimize negative impacts on nearshore areas.

As a semi-government institution, PICRC is also responsible for studying Palau's network of MPAs (both inside and outside the protected area), including both design of the MPA network and effectiveness of sites. PICRC is also conducting several lines of research under the SATREPS Program[1] that will contribute to understanding of climate change impacts and effective management of nearshore resources under those climate impacts.

Table 1. PICRC's regular monitoring schedule

Year	Q	Monitoring Work
1	1	Fish stock surveys at 100 locations around Palau. Started in 2017. See Map, right.
	2	
	3	PAN MPA surveys: survey 2 main habitats of 14 PAN MPAs as well as reference non-protected area located nearby. One MPA per month is surveyed at the same time of the year as the previous surveys to allow for comparison through time as well. Baseline surveys started in 2014-2016. Follow up surveys were conducted in 2017-2018.
	4	
2	1	
	2	
	3	Long term coral reef monitoring surveys (CRM) at 24 permanent monitoring sites to assess status and trends of coral reefs in Palau. Surveys conducted from October to December every even year.
	4	



Map, above. PICRC's long-term coral reef monitoring sites.

[1] Science and Technology Research Partnership for Sustainable Development (SATREPS), with the Japanese Government and JICA.

Coral Reef Research Foundation

Water temperatures

Water temperatures throughout Palau have been monitored closely by the Coral Reef Research Foundation (CRRF) since 1999 to the present day through what has been described as "the most comprehensive water temperature monitoring network in the world" (Dr. Craig Steinberg, Aus. Inst. Mar. Sci., pers. comm.). The network consists of 65 stations with over 140 recording thermographs installed at depths from the reef shallow to 90 m deep, from lagoon inshore areas to deep outer slopes. The network presently generates about 25 million temperature measurements a year with a data base that goes back to 1999. A twenty-year look at water temperatures on the outer slopes of Palau was published by Colin (2018, see Fig. 3) and earlier data sets were included in Colin (2009, 2016), Colin and Lindfield (2019), and Martin et al. (2006).

Weather

Marine weather parameters are monitored by CRRF and CORDC Scripps Institution of Oceanography at the Ongiang Island X-Met station (palauweather.org). The program has also maintained a XMet station at Helen Reef and Kayangel, but are presently off line. CRRF has an additional weather station at Ngeanges Island (Rock Islands) and within Jellyfish Lake. These have been reporting since 2007 with near complete weather data coverage. See Photos, p. 21).

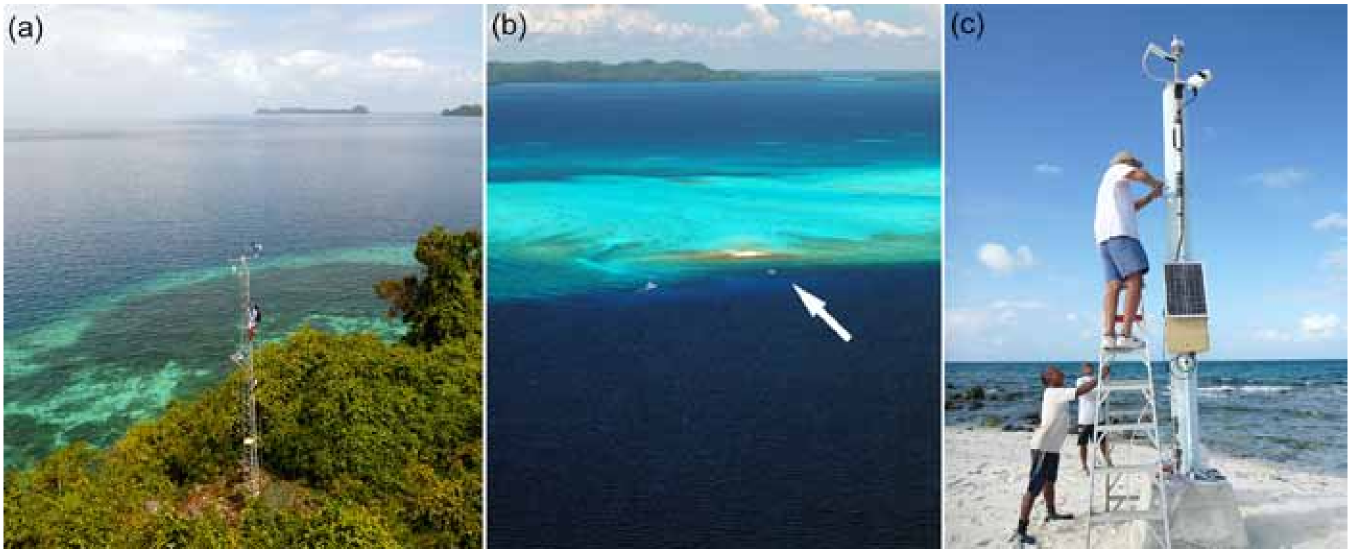
Currents

HF radar network. Surface currents have been monitored for the three years by a system of three HF radar station (Angaur, Melekeok, Kayangel) with provide current information hourly on a 6 km grid scale.

Currents along the Palau barrier reef were monitored continuously by ADCP instruments from 2014-2018. This has now been reduced to a single station located on Hydrographer Bank (Lukes) to monitor North Equatorial/Equatorial Counter current flows between Angaur and Peleliu.

Bathymetry

CRRF and Scripps Institution of Oceanograph have been engaged in mapping bathymetry around all islands and reefs in



Photos, above. (a) Ngeanges Island weather station. (b) Oningiang Island on western barrier reef, location of the XMet weather station which acquires unobstructed marine weather. (c) XMet station being installed on Oningiang Island. Photos copyright Coral Reef Research Foundation, 2019. Used with permission.

Palau since 2014. Cruises on the R/V Roger Revelle mapped the deep perimeters of all islands and reef in Palau from 2014-2017, with data provided to PALARIS. Selected shallower areas along the outer reefs have been mapped by multibeam sonar since 2015, but only about 5% of the perimeter of the main island/reef has been mapped. None of the outer island and reefs have been done. New work by CRRF is intended to map the entire outer perimeter of Palau's reefs from 10 to 300 m depth by the end of 2021.

Selected inshore areas have been bathymetrically mapped by single point sonar from 2002-2018 resulting in many usable bathymetric charts for scientific purposes. Extensive areas (approximately 150 km2 area) of the western lagoon have been mapped by side scan sonar by CORDC Scripps, resulting in the discovery of extensive mesophotic reef tracts at depths of 30-36 m (Colin and Lindfield 2019) which were previously unknown. The side scan mapping also provides details on structures in this area which has very low water visibility on the bottom.

Global Climate Change

Work conducted through CRRF has resulted in landmark studies of climate change in Palau. These include analysis of conditions over several thousand years; mostly from coring in marine lakes whose bottom sediments represent an unique undisturbed record on climate. The role of extended drought, due to shifts in the ITCZ, are critical in maintaining adequate rainfall in Palau (Sachs et al. 2009). More recent work (Sachs et al. 2018, Richey and Sachs 2016, Conroy et al. 2017) has provided a large amount of current and historical information.

Biodiversity and Mesophotic Coral Reefs

The CRRF marine invertebrate/plant biodiversity database is now online at https://biodiversity.coralreefpalau.org/. The web interface was supported by the Canada Fund for Local Initiatives and includes some 2,800 specimens from Palau, as well as many other countries. The collections covered in this database were largely taken as part of the US National Cancer Institute's Marine Collections program, for which CRRF was the global contractor from 1992 to 2014. The specimens remaining after the 2015 fire at CRRF have been transferred to the California Academy of Sciences in San Francisco and the Smithsonian National Museum of Natural History in Washington, DC. The database is searchable for most parameters.

Numerous new species of marine organisms have been scientifically described in recent years. Some examples of these include Anseeuw et al. (2017) and Samimi-Namin et al. (2016).

Mesophotic coral reefs (light-dependent corals and associated communities typically found at depths ranging from 30–40 m and extending to over 150 m in tropical and subtropical regions) have been suggested as important refuges for coral reefs from conditions (coral bleaching, overfishing, sedimentation) which have degraded many shallower reef worldwide. For Palau, this "mesophotic refuge" effect is not found based on various recent studies (Colin 2016b, Colin 2018, Colin and Lindfield 2019, Andradi-Brown et al. 2016). Overall the mesophotic reefs of Palau appear to have been deteriorating in the past 20 years, due to storm damage (Colin 2016b), bleaching (Colin and Lindfield 2019), and overfishing (Colin and Lindfield 2019, Lindfield 2017).

Mesophotic reefs have been discovered in the Palau lagoon, where none were thought to exist, and have been extensively mapped by autonomous vehicle using side scan sonar (Terrill et al. 2018). These reefs have probably existed since the rise of sea level flooded that previously dry Palau lagoon about 10,000 years ago (Colin and Lindfield 2019, supplementary materials). They are in an area of extremely high sedimentation and the anomalous conditions under which they live and survive are being documented in detail.

Aspects of the biodiversity of mesophotic reefs in Palau have been described by Sinniger et al. (2016), Colin (2016) and Colin and Lindfield (2019). While Palau has a diverse array of species found in deeper reef waters, the overall diversity is less than areas to the west and south (Philippines, Indonesia). The zoogeography of mesophotic species is poorly known, mostly due to a general lack of collections from most areas.

NEARSHORE FISHERIES

Photo by A. Gupta

Information for this section was provided by many partners, including: PICRC, CRRF, Bureau of Marine Resources & MNRET, PALARIS, The Nature Conservancy, and Conservation International. Additional information was found in published technical reports and journal articles.

State of Nearshore Fisheries

The vast majority of indicators for nearshore fisheries are in Fair to Poor condition, and getting worse. There are many unknowns. Where there is data, it shows that reef fish biomass, abundance, and size are lower than expected. Several species are at risk of a population crash (either locally or widespread). It also appears that invertebrates have been overfished (either locally or widespread). There are key missing pieces of information, including fishing yield, destination, and consumption. This missing information on the State of Nearshore Fisheries thus limits responses.

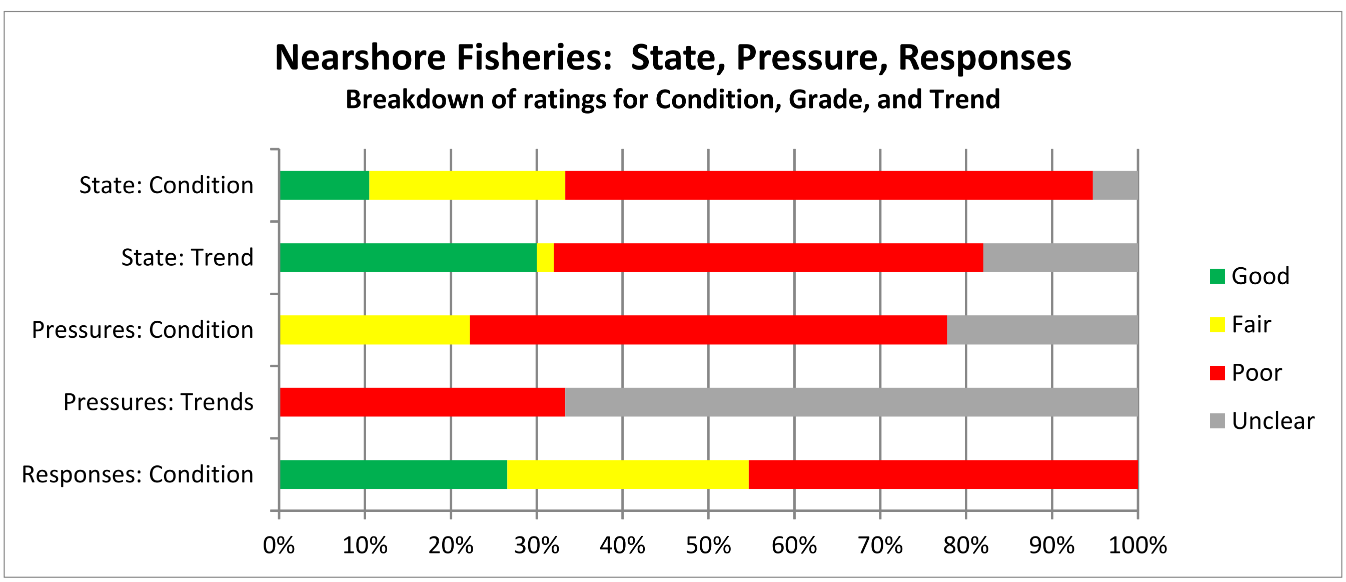
Pressures on Nearshore Fisheries

Pressures on Nearshore Fisheries come from local stressors as well as changing environmental conditions due to climate change. Where they are understood, pressures appear to be getting worse.

Responses for Coral Reefs

Palau's response to Nearshore Fisheries has been inadequate. Investment in MPAs has yielded some good results, but it is not enough. The majority of reef fishery resources are not protected via MPAs or rules and regulations, and there are key gaps in knowledge that are essential for managing nearshore fisheries. Alternatives to nearshore fishery use, such as aquaculture and offshore fisheries, are not yet functioning enough to reduce pressure on nearshore fisheries, and may not divert enough consumption to stop population crashes. Palau's National Government has invested relatively little into managing Nearshore Fisheries; a wide and disparate group of local and international nonprofits, semi-government institutions, and academia have taken on the responsibility but with little coordination. Information on nearshore fisheries is thus widespread and at times, conflicting.

Palau must approach Nearshore Fisheries with a comprehensive, coherent response, using the coordinated strengths of multiple actors; as it does with coral reefs. This response must also be gender and socially inclusive (e.g. not just focus on reef fish).



SDG 14.4.1

SOE Indicator 16. Abundance of Commercially Important & Large Fish

This indicator provides evidence that the number of Palau's reef fish are much lower than expected and still declining; however, the presence of high variability within the samples and among years makes it difficult to accurately analyze these trends.

Although this indicator is not new, it has been changed in the way it is presented and evaluated. The 2017 SOE assessed the indicator across all locations and depths, which masked the unique characteristics of individual sites. This reports maintains the unique data for each location and depth.

The 2017 SOE applied a subjective grade, based on best knowledge, that indicated abundance values were very low. This report instead uses a more repeatable method similar to that used for Live Coral Cover and Biomass, by comparing observed to a defined "expected" value.

		State[1]	Maximum[2]	Trend[3]	Condition[4]
Location	*Depth*	*fish/100m^2*	*(2005) #fish/100m^2*	*2005-2016*	*2016*
Inner Bay Reefs	3 m	3.4	7.5	Stable	Poor *45% of expected*
Inner Bay Reefs	10 m	2.7	8	Stable	Poor *34% of expected*
Western Outer Reefs	3 m	6.9	16	Decreasing	Poor *43% of expected*
Western Outer Reefs	10 m	9.7	16	Decreasing	Fair *61% of expected*
Eastern Outer Reefs	3 m	7.1	25	Decreasing	Poor *28% of expected*
Eastern Outer Reefs	10 m	7.2	33	Decreasing	Poor *22% of expected*
Patch Reefs	3 m	7.0	16	Stable	Poor *44% of expected*
Patch Reefs	10 m	4.7	7.5	Stable	Fair *63% of expected*

Change (2017-2019)

The abundance of fish decreased in every location and at every depth between the two reporting periods (Figure I16).

As described above, the way the indicator is reported here has changed. This better represents the natural variability. Note the State column and the different scales used on the Y axes in Figure I16; outer reefs still have higher abundance values than other habitats.

These findings from the PICRC monitoring program provide useful information on the status of food fish over time, however, conclusions must be carefully made as this monitoring protocol was not designed for this purpose. PICRC has now implemented a monitoring program to accurately document food fish status and trends over time (Gouezo et al. 2017).

[1] Actual fish abundance values above provided by M. Gouezo (specifically for this SOE, December 2018).
[2] Maximum from Figure I16.
[3] *Notes on Trend*: Based on long-term trends reported in Gouezo et al. (2017).
[4] *Basis for Grade*: This sets the peak abundance observed in 2005 as the "expected" and compares observed to expected. Following the guidance for Biomass, Good = >90% of expected; Fair = 50-89% of expected; Poor = <50% of expected.

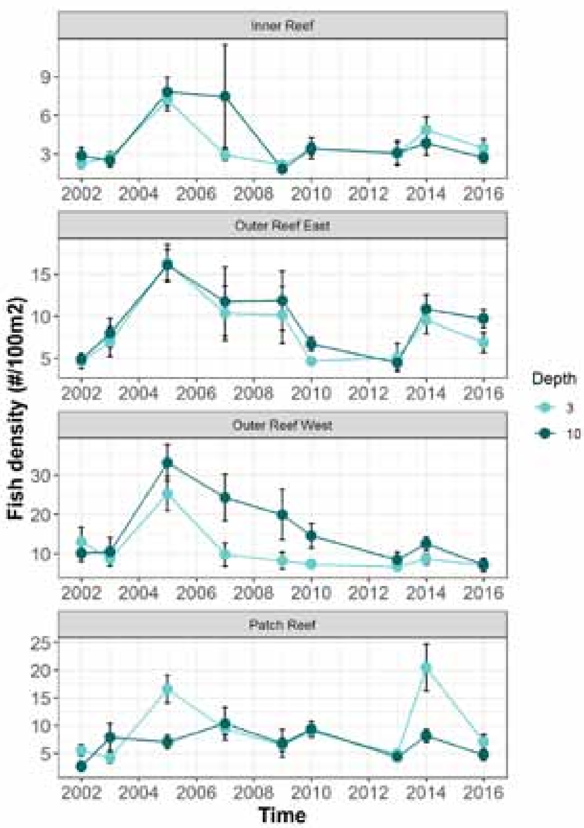


Figure I16 (right). Mean fish abundance per 100 m^2 (± SE) through time within each habitat and depth (Gouezo et al. 2017).

SDG 14.4.1

SOE Indicator 17. Biomass of Commercially Important and Large Fish

For most locations, this fisheries-independent indicator provides evidence that fish biomass (which combines number and size of fish observed) of Palau's reef fish is lower than expected.

This indicator is presented here in a different format than in the 2017 report. In the previous report, the Eastern and Western Outer Reefs were combined into one "Exposed reefs" indicator, and the Inner Bay and Patch Reefs were combined into one "Sheltered reefs" indicator. The 2017 SOE Report differentiated between protected and unprotected reefs. The two-year interval between reports has not been enough time to re-survey and re-analyze all MPAs in order to provide an overall meta-analysis of biomass in MPAs. Data in this 2019 Report were not combined across locations and depths, providing a more complex but more accurate indication of trend and condition of biomass.

		State[1]		**Trend[2]**	**Condition*,[3]**
Location	*Depth*	*2016*		*2007-2016*	*2016*
Exposed Reefs		*g/m²*	*kg/hectare*		
Western Outer Reefs	3 m	54.2	542	No clear trend	Fair *76% of expected*
Western Outer Reefs	10 m	78.5	785	No clear trend	Good *110% of expected*
Eastern Outer Reefs	3 m	58.6	586	Decreasing	Fair *82% of expected*
Eastern Outer Reefs	10 m	22.8	228	Decreasing	Poor *32% of expected*
Sheltered Reefs					
Inner Bay Reefs	3 m	12.6	126	Stable	Poor *49% of expected*
Inner Bay Reefs	10 m	16.7	167	Stable	Fair *65% of expected*
Patch Reefs	3 m	11.8	118	Decreasing	Poor *46% of expected*
Patch Reefs	10 m	9.7	97	Decreasing	Poor *38% of expected*

Change (2017-2019)

Between the reporting periods, biomass increased slightly in several locations and depths, but continued to decline in Patch reefs. Note that the biomass values in the 2017 SOE were from 2016. The same data here are unique for location and depth.

These findings from the PICRC monitoring program provide useful information on the status of food fish over time, however, conclusions must be carefully made as this monitoring protocol was not designed for this purpose.

* Gouezo et al. (2017) stress that the biomass thresholds presented in MacNeil et al. (2015), which form the basis for assigning a Condition here, are only applicable to Outer Reefs. In the absence of other comparable thresholds, this report continues to use them to evaluate other habitats. The caveat is clear: these comparisons are for policymaker guidance only.

[1] Actual biomass values above provided by M. Gouezo (specifically for this SOE, December 2018).

[2] *Notes on Trend:* Based on long-term trends reported in Gouezo et al. (2017).

[3] *Basis for Condition:* As defined in the 2017 SOE: Pristine, unfished locations average 1000-1200 kg/ha; 900 kg/ha is when structure starts to change; in most places 500 kg/ha is a threshold for functioning reefs, and 100 kg/ha is a potential crash point (McClanahan et al. 2016, MacNeil et al. 2015, McClanahan et al. 2007). Harbourne et al. (2016), on a study of Micronesia, defined a functionally intact reef as having biomass that was >50% of potential biomass and a fully functioning fish assemblage to be >90% of potential biomass. The 2017 SOE presented the values of biomass for Exposed and Sheltered Reefs within MPAs, which were defined as the "expected" biomass by location. Using Harbourne's definitions and setting the MPA values as the expected biomass, these Conditions follow:

- Outer Reefs: Setting the exposed reef MPA biomass of 714 kg/ha as "expected": Good = >90% of exposed reef MPA; Fair = 50-89% of exposed reef MPA; Poor = <50% of exposed reef MPA.
- Inner and Patch Reefs: Setting the sheltered reef MPA biomass of 258 kg/ha as "expected": Good = >90% of sheltered reef MPA; Fair = 50-89% of sheltered reef MPA; Poor = <50% of sheltered reef MPA.

Figure I17 (next page). Mean fish biomass in g per m² (b) (± SE) through time within each habitat and depth. Note: for fish biomass, samples in 2009 were excluded because of large observer errors and/or no accurate size estimations were conducted.

SOE Indicator 18. Trochus

A spring 2016 Stock Assessment of trochus by BMR and PICRC estimated the total population of trochus (from Kayangel to Peleliu) at 1.8 million individuals. The density and percentage of population that was 3 inches or larger (legal size) was lower than previously recorded in Palau and lower than near pristine locations elsewhere (Gouezo et al. 2016b). Gouezo et al. (2016b) recommended against allowing any harvest.

State[1]					Trend
	1956	*2002*	*2010*	*2016*	*2002-2016*
Individuals/Hectare	600-800	961		281	Decreasing
>3 in ind/ha			341	162	
% > 3 in		70%		57.5%	

[1] Gouezo et al. (2016b) citing McGowan (1957), Kitalong (2002), BMR (2010), and Dolorosa et al. (2010)

SOE Indicator 19. Sea Cucumber Size

Pakoa et al. (2014) surveyed sea cucumbers in the field in 2012, and compared sizes to a 2007 survey.

- Molech: No clear change in mean size. Notable decrease in frequency and fewer specimens in 2012 than in 2007.
- Cherumrum and Bakelungal: No change in mean size.
- Ngimes: Increase in mean size.
- Mermarch: Increase in mean size in Ngatpang, slight decrease in Ngarchelong

SOE Indicator 20. Clams (on reefs)

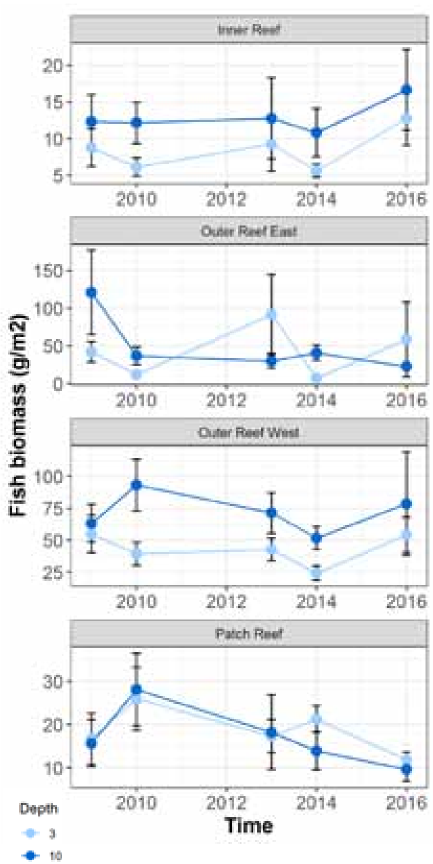
Trends in clam (*Tridacna crocea, T. maxima, T. squamosa, T. derasa, and T. gigas*) density were found to be significantly different among habitats and between depths (Gouezo et al. 2017). There is insufficient information to assign a Condition. See Figure I20a-d.

State[1]	Trend
	2010-2016
Inner reef • Very low abundance at 10m	Decreasing
Outer Reef West	Increasing
Outer Reef East • Greatest abundance in 2016; dominated by <5 cm-size clams	Increasing
Patch Reefs • Very low abundance (<1/100 m^2)	No Clear Trend

Change (2017-2019)

The 2017 SOE collapsed data on Macroinvertebrates/Clams from all locations and reported that clams were Declining. This 2019 SOE maintains the unique data for each location, providing a more accurate trend by location. The two years between the two reporting periods was likely enough time for new recruits, from a recruitment pulse following the 2012-2013 typhoons, to grow large enough to be observed.

[1] Gouezo et al. (2017).



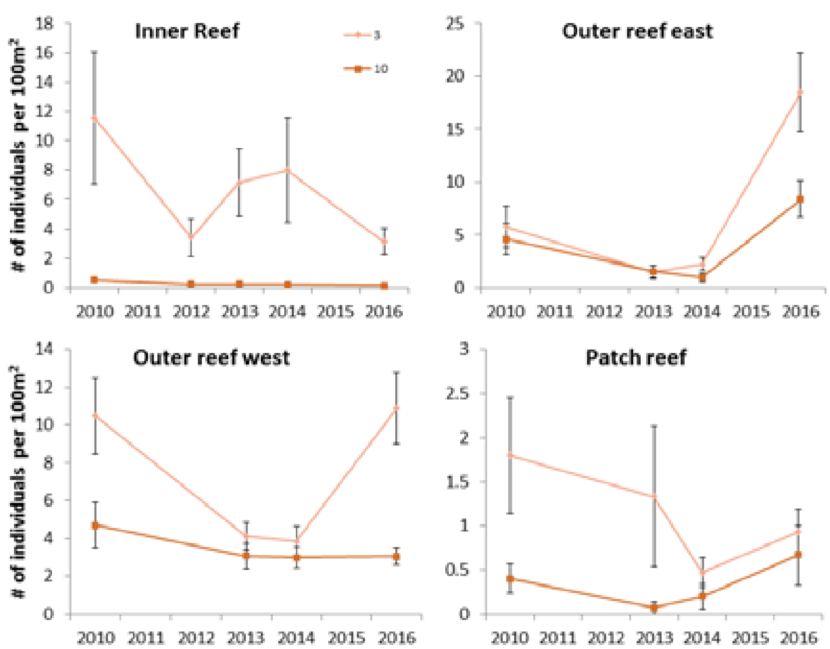


Figure I20a-d. Mean clam abundance per 100 m^2(± SE) through time within each habitat and depth (Gouezo et al. 2017).

SOE Indicator 21. Sea Cucumbers Stocks

Numerous site and species indicators show that Sea Cucumbers have populations and densities below sustainable limits.

The 2017 SOE report did not adequately cover Sea Cucumbers, and relied on Pakoa et al. (2009) to assign grades of Fair to Good for select species and locations. However, Pakoa et al. (2009) was written several years before a massive harvesting event in 2011, which depleted populations below sustainable conditions in several locations.

Golbuu et al. (2012) found that Sea Cucumbers declined by 88% outside the Ngardmau MPA and by 80% inside the MPA (due to illegal harvesting). Ngardmau's populations still had not recovered by 2014 (Rehm et al. 2014). Pakoa et al. (2014) found drastic declines in Ngarchelong and Ngatpang, with 87% and 97% respective declines of Cherumrum in each location (Figure I21).

Sea cucumber stocks can be depleted rapidly because of their sedentary behavior, late sexual maturation, density-dependent reproduction traits and lengthy pelagic larval stages (Gouezo et al. 2018-Teluleu). Gouezo et al. (2018-Teluleu) suggests that small MPAs are inadequate protection for Sea Cucumbers.

Barr et al. (2016) recommended a minimum 10-year recovery period (or until the population returned to 2009 status) before allowing any new harvest. Barr et al. (2016) also recommended a more sustainable 5% harvest per year, rather than a population-depleting harvest of 20% of the population every three (3) years. This 5% regime would yield a total harvest over time that was 13.6% higher than the 20%/3-year regime does, thus making it the more economical and environmentally-friendly choice (assuming no illegal harvesting in the MPA or overharvesting, plus adequate monitoring and enforcement systems). Pakoa et al. (2014) cautioned against opening sea cucumber harvest in many States at once, and recommended a system of rotating openings. They also recommended having long periods of rest (no harvest) and short open seasons.

<table>
<tr><th></th><th colspan="4">State</th><th>Trend</th><th>Condition</th></tr>
<tr><td>Location/Study</td><td>Past population and/or density</td><td colspan="3">Most recent population and/or density</td><td></td><td></td></tr>
<tr><td>Teluleu MPA, Peleliu[1]</td><td>Outside the MPA (Reference Site)
• 2012[2]: ~1.4 individuals/50m^2
• 2015[2]: ~0.1 individuals/50m^2</td><td colspan="3">• Fluctuate outside MPA, Steady inside MPA
• 2018: ~0.3 ind/50m^2 (~1 ind/100m^2)</td><td>No clear trend</td><td>Poor[3]</td></tr>
<tr><td>Ngemai MPA, Ngiwal[4]</td><td>• 2015[5]: ~114 individuals/100m^2</td><td colspan="3">• 2018[5]: ~2 individuals/100m^2
Slightly more outside the MPA</td><td>Decreased</td><td>Poor[3]</td></tr>
<tr><td rowspan="5">Ngardmau (Ngermasech MPA and Ngerikerker Reference Site (open))[6]</td><td></td><td>2009</td><td>2012</td><td>2014</td><td></td><td></td></tr>
<tr><td>MPA - Density (ind/50 m^2)</td><td>131</td><td>102</td><td>115</td><td>Increasing</td><td>Fair[7]</td></tr>
<tr><td>Reference - Density (ind/50 m^2)</td><td>99</td><td>12</td><td>6</td><td>Decreasing</td><td>Poor[7]</td></tr>
<tr><td>MPA - Total (individuals)</td><td>3269</td><td>2552</td><td>2866</td><td>Increasing</td><td>Fair[7]</td></tr>
<tr><td>Reference - Total (individuals)</td><td>2445</td><td>295</td><td>134</td><td>Decreasing</td><td>Poor[7]</td></tr>
<tr><td>Ngarchelong[8]</td><td>2007
• Ngimes (Stichopus vastus) = 17,445 ind/hectare[8]
• Cherumrum = Stable populations with larger individuals[9]</td><td colspan="3">2012[8]
• Ngimes (Stichopus vastus) = 3592 ind/hectare
• Cherumrum (Actinopyga spp.) = 87% reduction from 2007</td><td>Decreased</td><td>Poor[7]</td></tr>
<tr><td>Ngatpang[8]</td><td>2007
• Cherumrum = Stable populations with larger individuals[9]</td><td colspan="3">2012[8]
• Cherumrum (Actinopyga spp.) = 97% reduction from 2007</td><td>Decreased</td><td>Poor[7]</td></tr>
<tr><td>Coral Reefs[10]</td><td></td><td colspan="3">2016: < 2 ind/ha (0.02 ind/100 m^2)</td><td></td><td>No basis</td></tr>
</table>

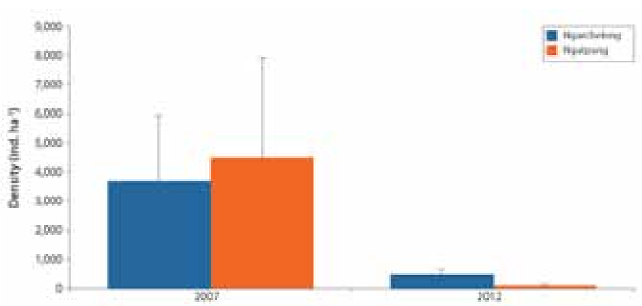


Figure I21. Density of Cherumrum (*Actinopyga* spp.) for Ngarchelong and Ngatpang for 2007 and 2012. (Figure 17 in Pakoa et al. 2014).

[1] Gouezo et al. (2018-Teluleu).
[2] Estimated from Figure 7 in Gouezo et al. (2018-Teluleu).
[3] A similar unpoached location in the Indian Ocean had a density of sea cucumbers between 4 and 27 ind/100 m^2. Following methods used for biomass and reef fish abundance, Good = >90% of expected; Fair = 50-89% of expected; Poor = <50% of expected. The population in Teluleu is less than 25% of this expected population. "There has been no sign of recovery" in the MPA (for sea cucumbers).
[4] Gouezo et al. (2018-Ngemai).
[5] Estimated from Figure 5 in Gouezo et al. (2018-Ngemai) plus text reference for difference of "57 times higher". The population in Ngemai is less than 50% of expected (See [3]).
[6] Rehm et al. (2014).
[7] See [3]. Ngardmau's MPA is at 87% of its pre-harvest condition; Reference site is at 6% of its pre-harvest condition.
[8] Pakoa et al. (2014)
[9] Pakoa et al. (2009)
[10] PICRC Monitoring Sites. Gouezo et al. (2017)

Overview: Fish Size Indicators (Indicators 22-24)

	% Immature Fish	Size of Fish Caught	Spawning Potential Ratio (SPR)	
Palauan name	*Condition of % immature*	*Trend in Size Caught*	*Trend in SPR*	*Condition of SPR*
Ngyaoch/Berkism	Poor	Increased	Increased[2]	Poor
Keremlal	Poor	Decreased	Decreased	Poor
Kedesau	Poor			Fair
Udech	Good	No change	Increased[2]	Poor
Melangmud	Poor			Poor
Mechur	Good	Increased[5]	Decreased	Poor
Erangel	Good	No change	Decreased	Fair
Chum (Um)	Good	Decreased	Decreased	Poor
Klesebuul (*S. lineatus*)	Insufficient data	Increased	Increased[2]	Poor
Klesebuul (*S. punctatus*)	Fair			
Beyadel/Ngesngis	Poor			
Otord/Undoudungelel	Poor			Poor

SOE Indicator 22. Percent immature fish caught

Landings in Koror in 2014 and 2015 included many fish that were immature. The "Percent Immature" indicator does not alone indicate overfishing or likelihood of population collapse (see Indicators 23-24; SPR is a better indicator of overfishing).

In the Northern Reefs, 18% of fish caught (for which there was established Size of Maturity) were immature in 2015-2016 (Lindfield et al. 2016). Management reduces the percent of fish caught immature: in 2017 only 7% of Otord, 2 Melangmud, and 0 Keremlal were immature, according to records in the Northern Reefs Fisheries Cooperative database.[4]

Bejarano et al. (2013) tracked percent immature fish caught in 2009 for several species of interest; this was reported in the 2017 SOE. However, methods and understanding of size-at-maturity have changed. The table below indicates percent of fish caught immature, as reanalyzed and compared to Size at Maturity (Lindfield, unpublished, 2019, See [1]).

		State (Koror)[1]			Trend	Condition[2]
Palauan name	*Species Name*	*1982-1984*	*1990-1991*	*2014-2015*	*1982-2015*	*2014/15 (Koror only)*
Ngyaoch/Berkism	*Hipposcarus longiceps*	66%	58%	48%	Decreased	Poor
Mechur	*Lethrinus xanthochilus*	30%	15%	17%	Decreased	Fair
Keremlal	*Lutjanus gibbus*	2%	5%	8%	Increased	Good
Chum (Um)	*Naso unicornis*[3]	5%	12%	6%[5]	No clear trend	Good
Erangel	*Naso literatus*[3]	0%	0%	0%[5]	Stable	Good
Melangmud	*Lethrinus olivaceous*		26%	31%	Increased	Fair
Besechamel	*Monotaxis grandoculis*		25%	10%	Decreased	Fair
Otord/Udoudungelel	*Chlorurus microrhinos*		29%	56%	Increased	Poor
Kedesau	*Lutjanus bohar*	38%		78%	Increased	Poor
Udech	*Lethrinus obsoletus*		49%	27%	Decreased	Fair
Tiau (black)	*Plectropomus areolatus*	17%	27%		No clear trend	
Ksau	*Epinephelus polyphekadion*	37%	14%		No clear trend	

[1] These values were provided by CRRF for this report (Dr. Steven Lindfield, unpublished, 2019), by comparing original size data from historical and recent studies to known Size at Maturity for species in Palau (Prince et al. 2015).

[2] *Basis for Condition:* Moore et al. (2015) calls "30% immature" the common reference value, and flags for concern species with >30% immature catches). Poor > 40%; Fair = 10-40%. Good < 10% (few fish caught immature).

[3] Size at maturity for *Naso literatus* and *Naso unicornis* combined estimate from Guam and Pohnpei (Taylor et al. 2014).

[4] Uses the Northern Reefs Fisheries Cooperative (NRFC) database; August 19 to December 26, 2017. Sample sizes were small (9-10 of most species; 18 Melangmud; 65 Keremlal, 84 Otord). Data is self-reported. Sizes of recorded Otord, Melangmud, and Keremlal were cross-referenced with L_{50} from Prince et al. (2015) to count if and how many fish were below L_{50} (and thus defined immature).

[5] This data must be considered in the context of other data. Moore et al. (2015) did not record many immature Erangel being caught, but did find that total mortality was more than double the recommended maximum fishing mortality. (Regardless of size, too many Erangel were being caught). Similarly, Moore et al. (2015) noted that mortality rates of Chum were too high and thus it was likely overfished.

SDG 14.4.1

SOE Indicator 23. Size of Fish Caught

Several species of fish are still being caught too small: particularly Keremlal, Mechur, and Chum (Um), (although size information must be considered in relation to reproductive potential, see Indicator 24).

Moore et al. (2015) surveyed 15 fishermen in 2014; 80% perceived that the size of fish had decreased over the past five years.

The size of fish being caught varies by species, location, time of year of study, and other variables. However, it is clear that certain species are being caught before they become mature, putting the population at risk of not being able to replenish itself. Lindfield (2017) compared data from 1982-1984 (when there was already fishing pressure), 1991-1992, and 2014-2015 to determine trends in the sizes of fish being caught and processed in the Koror fish market. Moore et al. (2015) also measured sizes of fish caught, but Lindfield (2016) adjusted and improved the method (shortened, more fisher-friendly survey form; more survey months; and use of stereo-video camera over manual methods to determine size) and thus it is used here. There are some differences in the data; differences may be due to changes in the method or natural variability in what was caught and processed in Koror in 2014 and 2015 (See [9]).

For three species, there has been a critical drop in the average size of fish caught, and thus in spawning potential (e.g. ability to replenish the population): Keremlal, Chum, and Mechur. Other species have average caught sizes that indicate their population is already below the level needed to replenish itself. Although many more species of fish were surveyed (over 30 species), there was only adequate data at the three different time periods to analyze size trends in the species here.

For most species, there is not enough data to assess life history parameters (such as size at maturity). Thus it is not possible to tell if other fish are being fished as sustainable or unsustainable levels; and it is not possible to set a biologically relevant size limit.

		State				**Trend**	**Condition**	
Palauan name	*Scientific name*	*Average size of fish caught (mm)*				*1984-2015 (Koror only)*	L_{50}[3]	*Description from Lindfield (2017)*
		Koror			*N Reefs*			
		1984[1]	*1991*[1]	*2015*[1]	*2017*[2]			
Ngyaoch/ Berkism	*Hipposcarus longiceps*[9]	284	295	306	[2]	Increased[9]	300	Average size caught is close to size at maturity.
Keremlal	*Lutjanus gibbus*	287	278	272	326 (N=65)	Decreased	245	Obvious lack of larger fish in 2015. Removal of large fish from population; impaired reproductive potential.
Udech	*Lethrinus obsoletus*[9]	259	246[4]	258		No change[9]	236	Life history not well understood.
Erangel	*Naso literatus*[9]	241	242	240	[2]	No change[9]	205	Most fish caught are large enough to be mature.
Mechur	*Lethrinus xanthochilus*	372	392	377	426 (N=17)	Increased[5]	326	Fewer large fish caught. Decreased size from 1991.
Chum (Um)	*Naso unicornis*[9]	421	395	388	414 (N=9)	Decreased[9]	363	Fewer large fish caught. "Declined severely in 2015."
Klsebuul	*Siganus lineatus*[9]	222	238	254		Increased[9]	242	Reduction in both large fish and small fish. Possibly more selective fishing combined with minimum net size (3 in) requirement of 1994.
Ksau Temekai	*Epinephelus polyphekadion*	369	412[6]	Closed season		Increased[7]		
Tiau	*Plectropomus areolatus*	471	421	Closed season		Decreased[7]		More larger fish in 1984, but smaller sample size.
Meas	*Siganus fuscescens*	Size and numbers of pre-spawning aggregations of *Siganus fuscescens* in Airai were smaller than 20 years ago (2011)[8] (p. 197).						

[1] Average sizes taken from Figures 3a-3d in Lindfield (2017).

[2] Calculated average using data from the Northern Reefs Fisheries Cooperative (NRFC) database, with fish catches recorded from August 19 to December 26, 2017. One (1) single Ngyaoch/Berkism was recorded at 337 mm. No sizes were recorded for the few Erangel recorded. Prince et al. (2015) found that 60% of fish caught in the Northern Reefs were immature.

[3] L_{50} from Table 1 in Lindfield (2017). L_{50} used as approximate size at maturity.

[4] Much larger sample size in 1991, possible change in fishing practice.

[5] Troubling decrease from 1991, despite increase from 1984.

[6] 1991 may have been during aggregation.

[7] Insufficient data.

[8] Kitalong (2017) in Rengiil et al. (2017).

[9] Moore et al. (2015) and Lindfield (2017) findings were similar for Ngyaoch/Berkism and Klsebuul; but differed for Udech, Erangel, and Chum (Um). Kitalong (2017) in Rengiil et al. (2017) highlighted that the Marine Protection Act of 1994 had "resulted in fewer small, immature fish being caught," which is certainly true for some species. However, the data is not clear on the exact impacts of the restriction (and/or its compliance and enforcement).

SOE Indicator 24. Spawning Potential Ratio (SPR) of Fish Caught

Prince et al. (2015) and Lindfield (2017) analyzed Spawning Potential Ratio (SPR) which is a measure of how much reproduction potential remains in a population. (SPR of 100% means that a population is unfished; 0% means no reproductive potential (e.g. no males/females or no mature fish)). "If the spawning potential ratio is less than 20%, it suggests that there is not enough reproductive capacity for stock to increase and the numbers of fish will continue to decline if management is not imposed" (Kitalong in Rengiil et al. (2017), page 197). When SPR is below 20%, the population of a species of fish will have trouble repopulating itself after being fished; the fish stocks may collapse.

These findings are limited to catches processed in Koror. Moore et al. (2015) found that the average furthest distance traveled to find fish (using the Happy Fish Market in Koror as reference) was 26.6 km (16.6 miles).

		State			Trend	Condition[4]
		(Koror Only)				
Palauan name	*Scientific name*	*1984-1991*[1]	*2012*[2]	*2015*[1]	*1984-2015*	*Parentheses: Lindfield (2017)*
Ngyaoch/Berkism	*Hipposcarus longiceps*	13%	5%	22%	Increased[3]	Poor (Recruitment likely impaired)
Keremlal	*Lutjanus gibbus*	45%	10%	27%	Decreased	Poor (Critical drop. Needs intervention.)
Kedesau	*Lutjanus bohar*		27%			Fair
Udech	*Lethrinus obsoletus*	14%	3%	18%	Increased[3]	Poor (Recruitment likely impaired)
Melangmud	*Lethrinus olivaceous*		10%			Poor
Mechur	*Lethrinus xanthochilus*	32%		21%	Decreased	Poor (Critical drop. Needs intervention.)
Erangel	*Naso literatus*	32%		26%	Decreased	Fair (No increase in fishing pressure.)
Chum (Um)	*Naso unicornis*	40%		20%	Decreased	Poor (Critical drop. Needs intervention.)
Klsebuul	*Siganus lineatus*	17%		19%	Increased[3]	Poor (Recruitment likely impaired)
Otord/Undoudungelel	*Chlorurus microrhinos*		21%			Poor
Butilang	*Scarus ruboviolaceus*		7%			Poor

[1] Figures 4a-4d in Lindfield (2017).
[2] From Table 2 in Prince et al. (2015).
[3] These populations may be recovering (Lindfield 2017).
[4] *Basis for Condition*: SPR <25% (nearing 20% or below) = Poor.

SOE Indicator 25.

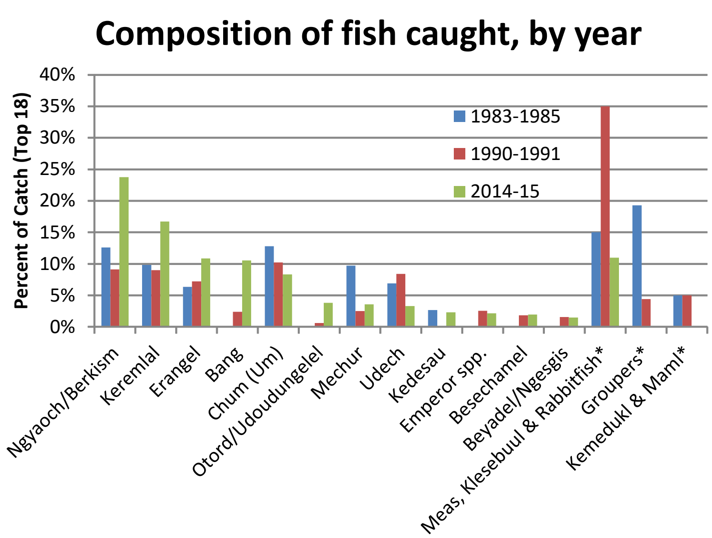
Composition of Catch

There appear to be shifts in catch composition, but these are not well understood. Figure I25 graphs the top 15 fish processed in Koror, as presented in Lindfield (2017). Tracking composition is important to observe secondary impacts of restrictions, such as shifts towards harvesting herbivores during the closed Grouper season (Bejarano et al. 2014). Composition varies by location.

Top catches, Koror compared to N. Reefs

	2015, Koror[1]	*2017, N. Reefs*[2]
Ngyaoch	28%	0.43%
Keremlal	19%	9%
Chum	10%	1.5%
Erangel	13%	0.28%

[1] From Table 2 in Lindfield (2016)
[2] From the NRFC Database (2018)



** Species are now restricted (seasonal or complete closures).*

Figure I25. Top 18 fish caught and processed in Koror, using data from Table 2 in Lindfield (2016). 2014-2015 saw a shift towards more Ngyaoch, Keremlal, and Bang; and fewer Mechur and Udech (plus shifts away from restricted species).

SOE Indicator 26.

Total Nearshore Fish Harvest

There are no new estimates of total annual nearshore fish harvest, which is a major gap. The 2017 SOE gave total harvest a "Poor" grade but it is not really possible to make an accurate assessment of total harvest because of the lack of data. Other fisheries indicators suggest that overfishing varies by location and by species.

The most recent estimate of total catch (Gillet 2016) used data from 2000. Estimated nearshore fishery harvest (for 2016) was 2,115 metric tons/year. This estimate has been the same since 2000 because there are no certain measurements of fishing take (Gillet 2016).

Total Nearshore Harvest (Gillet 2016)

Type	*Amount*	*%*
Reef and Seagrass—Subsistence	1250 mt/yr	59%
Reef and Seagrass—Commercial	865 mt/yr	41%
Total	2,115 mt/yr	

Reef fish harvest increased drastically from the early 1990s: 250 mt (1990), 450mt (1991), 554mt (1992) (Japan Overseas Fisheries Cooperation Foundation/FDAPIN 1994). Fish stocks were "moderately to optimally exploited and not overfished" (Kitalong and Dalzell 1994). By 2000 fish were being harvested at the rate of over 2000 mt/yr.

An estimated 60% of the harvest was used for subsistence purposes, although the proportion being sold directly to restaurants and hotels has increased in recent years.

Destination of Nearshore Harvests

Use	*Amount*	*%*
Subsistence Use[1]	1250 mt/yr	59%
Sold to stores and fish market[2]	560 mt/yr	26%
(Portion of store and fish market sales to restaurants and hotels[3])	(280 mt/yr)	(50% of that sold to stores)
Sold directly to restaurants and hotels[4]	200 mt/yr	10%
Exported[5]	105 mt/yr	5%
Total	2,115 mt/yr	

[1] Gillet 2016. Kitalong & Dalzell (1994) estimated 500-1100 tons/yr, including non-reef fish, and Golbuu et al. (2005) estimated the average subsistence reef-fishery catch in Palau from 1985 to 2005 to be 1200 tons/yr.
[2] Calculated
[3] Estimated from Singeo 2017, unpublished
[4] BMR 2015

The amount of fish being processed through the Koror fish market has held steady: In 2014 Moore et al. (2015) recorded 11.84 tons of fish in August; in 2015 Lindfield (2016) measured 10.44 tons in June and 11.77 tons in July.

There is also no single estimate of fish consumption. Hanich et al. (2018) reported a per person consumption of 79 kg/person/year.; Birkeland (2017) estimated 56 kg/person/year; Wabnitz et al. (2018) assumed 98 kg/person/year (given a range of estimates from 33 to 135 kg/person/year).

SOE Indicator 27.

Fisher Perceptions

Fisher perception surveys have not been repeated, so they cannot be compared directly to each other. But various surveys over the years of different populations suggest that increasingly more fishers are perceiving difficulty in finding reef fish.

Year	**State**
1991[1]	19% of women fishers said that there were fewer species of fish
2002[2]	31% of the fishers perceived that the inshore fishery was being over-harvested
2011[3]	Relative to when they started fishing: 95% said reefs were in worse condition; 90% said less fish; and 80% said smaller fish.
2014[4]	73% of fishers said quantity of fish caught has decreased
Trend	Increase (1990s-2000s vs. 2010s) (higher % reporting difficulty)

[1] Matthews (1992)
[2] BMR (2002, in Kitalong 2017)
[3] Rhodes et al. (2011)
[4] Moore et al. (2015)

SOE Indicator 28.

Invertebrate Harvest

During surveys of reef fish processed through the main fish market in Koror, Lindfield (2016) recorded sales of invertebrates that represented 1% of the total catch surveyed. These amounts came from six (6) fishing trips (out of 54 total fishing trips surveyed):

- 104 lbs - Lobster
- 50 lbs - Giant Clam

Pakoa et al. (2014) reported that subsistence harvests of sea cucumbers have increased with increasing population.

Average annual harvest of raw sea cucumbers (wet) was 11.3 tons from 1989-1998. 50% was for subsistence use, 48% commercial use, and 2% exported for home use overseas. Commercial fishing and export were banned in 1994.

Between 2009 and May 2011, 27.3 tons of cucumbers were exported under an Aquaculture permit. Pakoa et al. (2014) reported this included illegally harvested wild sea cucumbers.

An open season from June to December 2011 resulted in the harvest of 10,638,675 individual pieces (1,160 tons (wet)). 72.5 tons (dry) were exported during the open season. This was a likely overharvest (see Indicator 21). Pakoa et al. (2014) maintain that Palau's ban on export has helped to prevent overexploiting of sea cucumbers, which are overharvested elsewhere. Molech (Sandfish) and Bakelungal (Black Teatfish) are globally endangered (EN on the Red List).

SOE Indicator 29. Catch per Unit Effort (CPUE)

Catch per unit effort (CPUE) has increased over time, indicating that fishers must put in more effort to catch the same amount of fish. There is plenty of variability, depending on the type of fish and the study. Catch increased for herbivores during the closed Grouper season in 2009, possibly exacerbating pressure on already overfished herbivore species.

	State		Trend
Type of fishing/fisher	*Previous time period*	*Recent/Current time period*	*Previous to Current time period*
Hand-line fishing	1992[1]: 3.49 kg/hr	2014[2]: 3.2 $\pm$ 0.4 kg/hr 2015[3]: 2.9 $\pm$ .08 kg/hr	Decreased (lower catch per effort)
Spearfishing	1992[1]: 8.5 kg/hr	2014[2]: 7.4 to 7.8 $\pm$ 0.8 to 1.1 kg/hr 2015[3]: 7 $\pm$ .06 kg/hr	Decreased
Net & Seine fishing	1992[1]: 5.1 kg/hr	2014[2]: 3.7 $\pm$ 1.3 kg/hr 2015[3]: 7 $\pm$ 2.2 kg/hr	No clear change (higher or lower catch, high variability)
Northern Reefs	"Before" (unspecified)[4]: ~50 kg/hr	2011-2014[5]: 6.1 kg/hr 107 lbs/8 hours = 2015-2016[7]: 4.3 individual fish/fisher/hour 2017[6]: 4.2 kg/hr (avg, calculated)	Decreased
Herbivores[8]	*March 2009 (Grouper Open Season)*	*July 2009 (Grouper Closed Season)*	Increased (per fish) No clear change (weight) Fishers targeted and caught more herbivores during the Grouper closure.
	3.94 $\pm$ 0.54 fish/fisher/hectare	7.01 $\pm$ 1.17 fish/fisher/hectare	
	3 kg/fisher/hectare	3 kg/fisher/hectare	
	CPUE (fish/fisher/hectare) doubled for Chum; and increased for Erangel and Ngyaoch/Berkism during the Grouper Closure		

[1] Dalzell (1996).
[2] Moore et al. (2015).
[3] Lindfield (2016).
[4] Ann Singeo, personal communication on 1/24/2017 at Ebiil, based on recollections of long-time fishers in the Northern Reefs.
[5] Ann Singeo, personal communication on 1/24/2017 at Ebiil, based on data collected from fishers in the Northern Reefs. Reported at "500 lbs/4-5 hours."
[6] Calculated using data from the Northern Reefs Fisheries Cooperative (NRFC) database.
[7] Lindfield et al. (2016).
[8] Bejarano et al. (2014).

Overview: Coral Reef indicators compared to Reef Fish indicators

		Condition - Live Coral Cover	Condition - Abundance	Condition - Biomass
Location	*Depth*	*Indicator 1*	*Indicator 16*	*Indicator 17*
Western Outer Reefs	3 m	Good	**Poor** *43% of expected*	**Fair** *76% of expected*
Western Outer Reefs	10 m	Very Good	**Fair** *61% of expected*	**Good** *110% of expected*
Eastern Outer Reefs	3 m	Very Poor	**Poor** *28% of expected*	**Fair** *82% of expected*
Eastern Outer Reefs	10 m	Very Poor	**Poor** *22% of expected*	**Poor** *32% of expected*
Inner Bay Reefs	3 m	Very Good	**Poor** *45% of expected*	**Poor** *49% of expected*
Inner Bay Reefs	10 m	Very Good	**Poor** *34% of expected*	**Fair** *65% of expected*
Patch Reefs	3 m	Good	**Poor** *44% of expected*	**Poor** *46% of expected*
Patch Reefs	10 m	Fair	**Fair** *63% of expected*	**Poor** *38% of expected*

Overview of Pressures on Nearshore and Reef Fisheries

Five (5) primary pressures and threats to coral reefs are discussed here. Order does not indicate importance or impact.

Export of Reef fish and invertebrates	Climate Change	Degraded Habitats	Overfishing	Gaps in knowledge, laws, regulations & investment
Indicators 30	*(Daily cumulative plus long-term impacts)* Indicators 31-32	Indicator 33	Indicator 34 Indicator 14	Indicator 35

SOE Indicator 30. Reef Fishery Export (by passenger flight)

Birkeland (2017) wrote: "Export from coral reefs is not natural... Local consumption rather than exportation is the natural process of the coral-reef ecosystem. Coral-reef ecosystems naturally export only about 1% of their gross primary productivity.... only about 10% is useful to humans (fisheries yield)" (p. 4). He continued "Palauans can probably sustain a subsistence reef fishery for themselves, especially if they leave a substantial portion of the large individuals in the targeted species" (p. 6).

Most export of reef fish has been banned. RPPL 9-50, passed in 2015, allowed for the export of up to 50 pounds of reef fish (during their open season and of legal size, and caught with legal gear) by persons traveling by passenger flights. The amount of mostly personal export has been steady in recent years, and is much lower than in previous years (the export of live reef fish was banned in 2008; see Figure I30a).

However, existing passenger exports included tens of thousands of fish from species that are in Poor to Fair condition for Spawning Potential (See Indicator 24 and Figure I30b). Increased exports in 2016 may have been due to the Festival of Pacific Arts and Palau's National Election (BMR 2016).

	State					Trend/Grade[7]
Type of export/ Fish Exported	*Early 2000s[1]*	*2011[2]*	*2015[3]*	*2016[4]*	*2017*	*2015-2017*
Total export (mt/yr)	400	213	103	121.2	97.4[6]	No clear trend
Commercial (mt/yr)			11.2	13.1	11.2[6]	No clear trend
Personal (mt/yr)			87.3	97	86.13[6]	No clear trend
Erangel (no. of fish/yr)				20,205[5]	18,420[5]	Fair (Decreasing SPR trend, Fair SPR condition)
Keremlal (no. of fish/yr)				15,344[5]	12,959[5]	Poor (Decreasing size and SPR trends; Poor SPR condition)
Kedesau (no. of fish/yr)				850[5]	891[5]	Fair (Fair SPR condition)
Melangmud (no. of fish/yr)				4,330[5]	2,364[5]	Poor (Poor SPR condition)
Invertebrates (non-commercial)			~35,000[3]	~42,000[4]		No basis

[1] FAO (2009)
[2] Rhodes et al. (2011) in Gillet (2016).
[3] BMR (2015)
[4] BMR (2016)
[5] Raw data from BMR's database on exports. Provided by MNRET in January 2019.
[6] BMR (2017)
[7] Grade follows that of Indicator 23 (Size) and Indicator 24 (Spawning Potential Ratio, SPR).

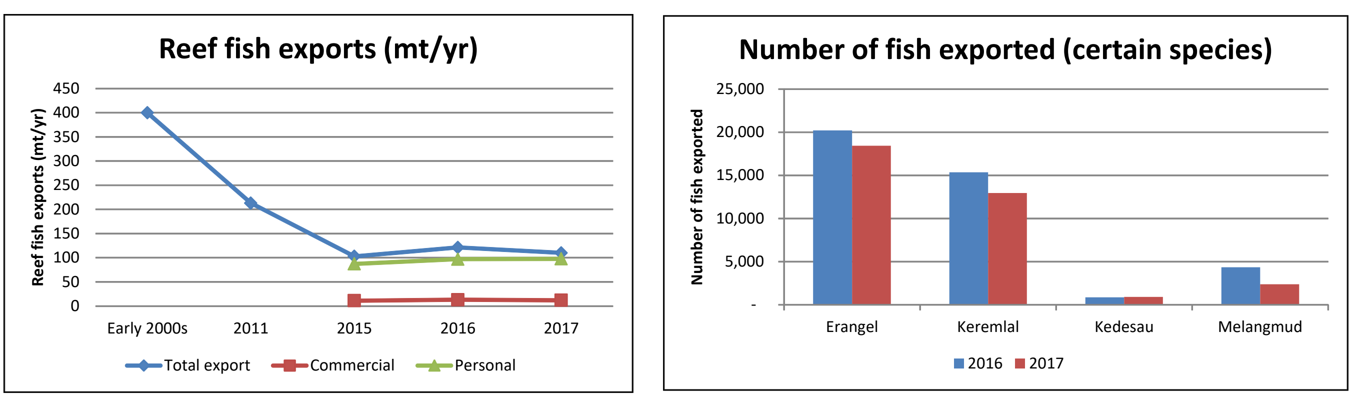


Figure I30a-b. a) Exports (mt/yr) over time. b) Number of fish exported for certain at-risk species.

Climate Change Pressures: Acidification, Ocean Temperatures

SOE Indicator 31. Declining Reef Fishery Productivity

Wabnitz et al. (2017) projected a 23% decline in reef fish abundance over 20 years due to climate change, even under a best case scenario (implementing Best Practices in tourism and consumption); and a 34% decline under current existing conditions (#5 from Table 2 in Wabnitz et al. 2017; Figure I30a).

Other studies predict reef fisheries will decline by 20% (Bell et al. 2016) to as much as 50% (Barange et al. 2014) by 2050 due to climate change. Global models suggest that productivity of fishery resources will decline by 6% (MacNeil et al. 2015), caused by a 2% annual loss of coral cover (van Hooidonk et al. 2007) and an average 4% reduction in primary productivity (Sarmiento et al. 2004). Barange et al. (2014) predicted a 50% or greater decline in phytoplankton productivity; they predicted a 76% decline in total reef fish catch in Palau by 2050; 50% of the decline will be due to climate change.

Reef fisheries declined in Palau after bleaching and typhoon events and took longer than coral to recover. Ngerumkaol Channel, a well-protected MPA, has been surveyed repeatedly for coral cover: 1991 at 52% live coral cover, 1999 at 24% (a loss of 53%), and 2006 and 2014 at 55%. In 1999 the abundance of commercially important fish was 57 fish/150 m^2 (calculated from Golbuu et al. 1999). In 2014 the site averaged 47 fish/150 m^2 (Gouezo et al. 2014); a possible a long-term decline in reef fish there of 18%. Given that the site is well protected as an MPA and live coral cover recovered, the decline is likely not due to overfishing but instead to the long-term effects of coral mortality in 1998, and the significant lag time it takes for fishery resources to recover. (See also Indicators 1, 16, 17 and Overview Table on p. 31). (Reef fish consumption is also partly responsible.)

Harborne (2016) mapped standing stock (biomass; Figure I31b) around Palau and compared the findings to fishing pressure (Figure I31c) and to potential standing stock in the absence of fishing (Figure I31d), finding:

- Fishing pressure was similar on western and eastern reefs.
- Despite similar fishing pressure, eastern reefs have lower standing stock (which was expected given the lower Live Coral Cover values due to typhoon damage).
- Removing fishing pressure nationwide would still yield lower standing stock on the eastern reefs, showing the effects of long-lasting climate impacts.

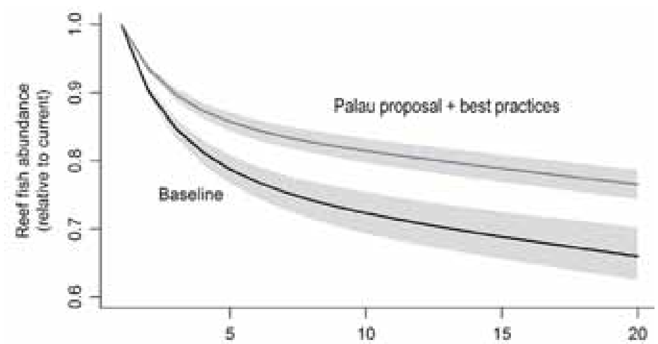


Figure I31a. Predicted reef fish abundance over time at current conditions (bottom) and under Best Practices (top line); climate change influences both. From Figure 6 in Wabnitz et al. (2017), p. 7).

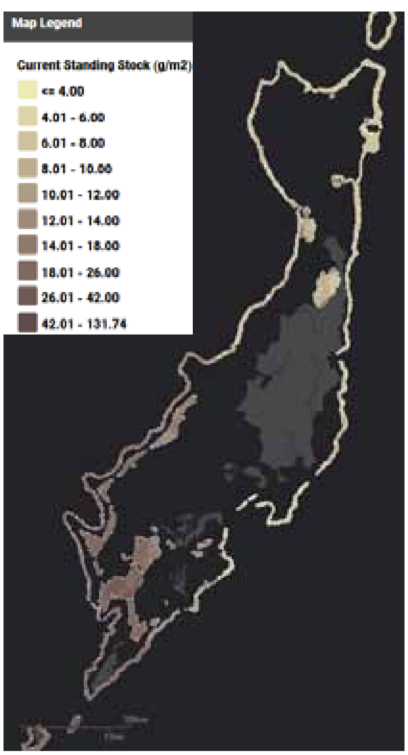


Figure I31b 5. Map of predicted *current* standing stock of 19 key fish species (Harborne 2016).

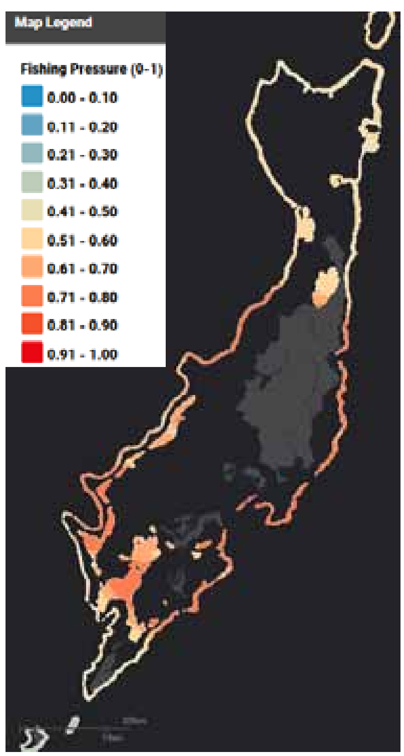


Figure I31c. Map of predicted relative *fishing pressure* around Palau. On a scale of 0 to 1, 0 is the lowest fishing pressure in the Micronesia region and 1 is the highest fishing pressure in the region (Harborne 2016).

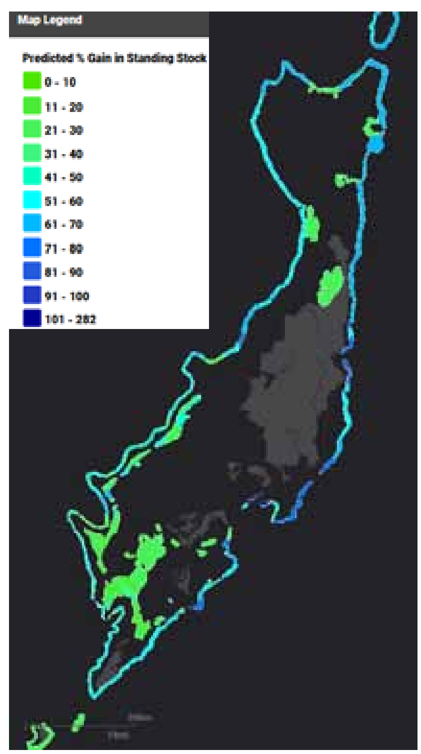


Figure I31d. Map of predicted *potential standing stock* of 19 key fish species if there was zero fishing (Harborne 2016).

Climate Change Pressures: Stronger Typhoons and Storms

SOE Indicator 32. Declining Seagrass Cover and Fishery Resources

This information was presented in the 2017 SOE, but is presented here again with more detail and analysis.

Seagrass habitats have been monitored as part of PICRC's monitoring program since 2011. Data from this period show a striking impact from Climate Change. In all four sites that are monitored annually, seagrass cover declined in 2012 and 2013 by 30 to 50% from their 2011 level (Mereb et al. 2016); this was likely a direct impact of Typhoons Bopha and Haiyan. Seagrasses recovered slowly after 2013, but in 2015 had not yet reached their pre-Typhoon Cover (Figure I32a).

Seagrasses are highly vulnerable to changes in Sea Surface Temperature, Solar Radiation, Stronger typhoons and storms, and changes in rainfall. Seagrass extent is expected to decrease by <5 to 20% by 2035 (Bell et al. 2011).

Fishery biomass and abundance (including fish, Rabbitfish, sea cucumbers, clams, urchins, and trochus) show varying possible impacts from climate change. Fish biomass declined in all sites between 2011 and 2015 (Figure I32b), and fish abundance declined between 2011 and 2014. Macroinvertebrate biomass has been consistently low (0.7 to 4.5 invertebrates per 100 square meters). Biomass declined both inside and outside MPAs (Figure I32b), suggesting climate impacts; but declines were greater in unprotected areas, suggesting non-climate drivers.

Figure I32a. Seagrass Cover over time (±SE) at 4 MPAs and reference sites (Mereb et al. 2016).

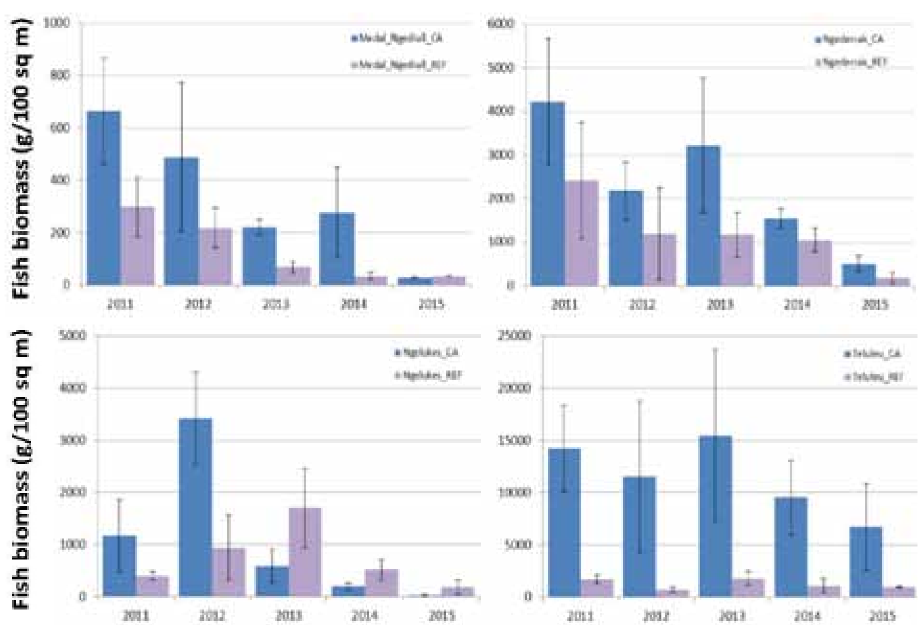


Figure I32b. Fish biomass in seagrass over time at 4 MPAs and reference sites (Mereb et al. 2016).

SOE Indicator 33. Degraded Habitats

Extent of habitat degradation and its impact on fishery resources, is unknown. See Indicator 12.

2003 estimates of lost fish catch from land-based pollution ranged from 3% to 30% (See table; Hajkowicz et al. 2003).

Gouezo et al. (2015) found an increase in juvenile fish abundance and a decrease in large parrotfish on eastern outer reefs after typhoon disturbance.

Golbuu et al. (2003) found that sediment from land was responsible for coral death; management of fishery resources must consider accumulating sediment.

In experiments, Wenger et al. (2014) found that reef fish larval development time increased by at least 9% under a sedimentation regime, which could negatively impact survivorship in the wild.

Table I33. Est. Lost catch (2003)

State	*Lost catch*
Angaur, Kayangel, Ngarchelong	3%
Ngardmau	8%
Ngaraard, Ngaremlengui, Ngiwal, Peleliu	10%
Koror	13%
Aimeliik, Ngatpang, Ngchesar	15%
Melekeok	18%
Airai	30%

SOE Indicator 34.

Overfishing

There is no simple answer to the question "How much and where are Palau's reef fish being overfished?"

Wabnitz et al. (2017) predicted tourism revenue and fishery status over the next 20 years, and found that the best outcomes would occur when tourist consumption of reef fish was reduced by 75% and local Palauans' consumption reduced by 30% (Table I34).

Table I34. Suggested change in consumption of reef fish under Best Practice scenario to maximize revenue

Type of consumption	*Reduced consumption under Best Practice Scenario*
Tourist consumption	75%
Local Palauan consumption	30%

Hanich et al. (2017) and Birkeland (2017) analyzed primary production and determined that the fishery resources being produced by Palau's coral reefs should meet future local subsistence needs.

However, most nearshore fishery indicators (14, 16-28) suggest that certain species have been overfished to the point that their reproductive potential has declined, with some species at risk of a population crash.

Fishing pressure on deeper reef environments (mesophotic reefs between 30-150 m) has intensified and overfishing has taken a toll. There are still significant stocks of fishes found there, but this may not persist in the future (Lindfield 2017; Colin and Lindfield 2019).

The majority of research has been done on fishery landings in Koror[1]. A researcher with TNC summarized initial findings from ongoing work using 2017 fish market data:

> "It seems like overall the fishery is doing not too bad ... but clear signs of over-exploitation are evident. First catches of most dominant species are dominated by smaller individuals, suggesting compromised stocks and ongoing density-dependence responses to fishing. Second, there seem to be clear geographical exploitation gradients, with fishers almost exclusively traveling to the far barrier reef to meet market demand, suggesting more compromised stocks at reefs near the populated island of Koror." (Javier Cuetos-Bueno, pers. comm., Jan. 2019).

Prince et al. (2015), in trying to determine Size at Maturity of fish in the Northern Reefs, noted that "in practice we found fully mature size classes difficult to sample because they have become rare in Palau" (p.55). Carlisle and Gruby (2018) wrote: "Targeted fish populations in the Northern Reef have been dwindling for what many believe to be decades. Most agree that overfishing is a primary cause" (p. 224).

Managers will need to assess by species and by location.

[1] Wabnitz et al. (2017), cited an estimate that 30-50% of reef fish landed in Koror are now being taken from the Northern Reefs (citing an unpublished TNC report by Gleason et al. 2014).

SOE Indicator 35.

Gaps in knowledge, laws, regulations & investment

There are significant gaps in knowledge that limit the application of regulations and responses:

- Little understanding of total harvest, sources, uses, destinations, and consumption.
- Little minimum and maximum size information (e.g. for only 12 out of 100+ species).
- Little specific seasonality information for species, thus few seasonal restrictions.
- No catch limits (or even estimates).
- Invertebrates are studied minimally.
- Little study outside Koror and Northern Reefs.

Adapting to change in fisheries has been slow; instead, there has been increasing fishing pressure in the face of decreasing resources, with little consideration of climate change.

Wabnitz et al. (2017) called for better enforcement in MPAs, especially remote ones, and Carlisle and Gruby (2018) found a high degree of compliance with MPAs and gear restrictions in the Northern Reefs, but also a high degree of non-compliance with species-specific laws. They also found that despite at least six overlapping decision-making "centers" in the Northern Reefs, their overall capacity for enforcement is weak.

Fishery resources appear to be undervalued (see Pakoa et al. (2014) discussion on sea cucumbers) and thus Fisheries tax and fee policies may favor overfishing.

Earthmoving and development policies are inadequate to stop sedimentation into fishery habitats.

The National Government's own entity for managing reef fisheries, the Bureau of Marine Resources (BMR), has limited capacity for such work (both financially and in terms of expertise). BMR conducts daily export surveys but does not conduct other regular reef fishery monitoring; research studies are *ad hoc* and usually with other organizations.

CEA (2016) determined Palau has "considerable under-investment in fisheries management. Compared to the global best practice of fisheries management accounting for roughly 6% of a country's fisheries value, the total fisheries budget in Palau is only 2.8%. The coastal fisheries budget is 2.7% of coastal fisheries value in Palau" (p. 35). BMR's annual budget of $550,000-$673,000 is supposed to cover reef fisheries, offshore fisheries, and aquaculture.

The majority of work being done on reef fisheries is being driven and financed by NGOs (national and international). Carlisle and Gruby (2018) concluded that NGO influence on Fishery Policy has enabled governance to adapt, but also write that NGOs are sometimes seen as controlling.

Type	*Gaps*
Information	Total harvest; Sizes and maturity; Invertebrates; Locations outside Koror and N. Reefs
Laws	Investment in Coastal Fisheries; Taxes and Fees
Regulations	Enforcement of MPAs and Species restrictions; Minimizing sedimentation

SDG 14.5.1

SOE Indicator 36. Extent of sustainable fisheries regulations

There are few laws and regulations in place to ensure sustainable fisheries beyond those for MPAs and gear restrictions. Few nearshore species have any seasonal, size, or harvest restrictions. There are no laws addressing sustainable population size and catch limits. The law on Maml and Kemedukl specifically addressed these two depleted species, but there is no legal mechanism for addressing other depleted species.

Of the fish and invertebrate species targeted for commercial and sustainable use, at least 79% of fish species and 75% of invertebrate types have at least one indicator showing signs of depletion among Indicators 18-28; whereas only 26% of fish and 25% of invertebrates types benefit from multiple restrictions, laws, and regulations.

					State (Number and Percent Regulated) and Grade[1]						
Type of Fishery	*Species or Types with 0, 1, or 2 signs of depletion[2]*				*Gear restrictions*	*Seasonal closure, Limited open period*	*Complete closure*	*Export ban*	*Size limit[3]*	*Catch Limit*	*Number under multiple regulations[4]*
	0	*1*	*2+*	*NI*							
Top fish species (19 fish species)	2 11%	10 53%	5 26%	2 11%	19 species 100%	3 16%	2 11%	3[5] 16%	2 11%	0 0%	5 26%
Macro-Invertebrates (4 types)[6]	0	2 50%	1 25%	1 25%	4 types 100%	1 25%	0 0%	2 50%	2 50%	0 0%	1 25%

[1] Grade follows general color scheme in SOE. *Basis for Grade:* Good = 90% or above; Fair = 50-90%; Poor = below 50%.
[2] Counts based on the table below showing number and type of restrictions per species or type. 0 means there are 0 indicators that were Poor or Fair. 1 and 2 mean the species has 1, 2, or more indicators that were Poor or Fair. NI means there was not enough information or the species was not assessed.
[3] Does not consider 3-inch minimum size net.
[4] E.g., at least 2 regulations (at least one other restriction, law, or regulation that is species- or type-specific, beyond gear restrictions).
[5] Fish species export bans only apply during the closed season.
[6] 4 types: Sea Cucumbers, Trochus, Clams, Crabs/Lobsters.

			State[1]	**Grade[2]**
Palauan name	*Scientific name*	*# Signs of depletion[3]*	*Type of additional restriction (beyond gear)*	
Kemedukl	*Bolbometopon muricatum*	*NI*	Complete closure	Good
Beyadel/Ngesngis	*Cetoscarus bicolor*	*1*	No additional restrictions	Poor
Maml	*Cheilinus undulatus*	*NI*	Complete closure	Good
Otord/Undoudungelel	*Chlorurus microrhinos*	*2*	No additional restrictions	Poor
Bang	*Parupeneus barberinus*	*0*	No additional restrictions	Poor
Ksau Temekai	*Epinephelus polyphekadion*	*0*	Seasonal closure, Size limit, Closed season export ban	Good
Ngyaoch/Berkism	*Hipposcarus longiceps*	*2*	No additional restrictions	Poor
Udech	*Lethrinus obsoletus*	*1*	No additional restrictions	Poor
Melangmud	*Lethrinus olivaceous*	*1*	No additional restrictions	Poor
Mechur	*Lethrinus xanthochilus*	*2*	No additional restrictions	Poor
Kedesau	*Lutjanus bohar*	*1*	No additional restrictions	Poor
Keremlal	*Lutjanus gibbus*	*2*	No additional restrictions	Poor
Erangel	*Naso literatus*	*1*	No additional restrictions	Poor
Chum (Um)	*Naso unicornis*	*2*	No additional restrictions	Poor
Tiau	*Plectropomus areolatus*	*1*	Seasonal closure, Size limit, Closed season export ban	Good
Butilang	*Scarus ruboviolaceus*	*1*	No additional restrictions	Poor
Meas	*Siganus fuscescens*	*1*	Seasonal closure, Closed season export ban	Fair
Klesebuul	*Siganus lineatus*	*1*	No additional restrictions	Poor
Klesebuul	*Siganus punctatus*	*1*	No additional restrictions	Poor
Sea Cucumber		*2*	Export ban	Fair
Trochus		*1*	Limited harvest period, Size limit	Fair
Clams		*1*	Export ban	Fair
Crabs and Lobsters		*NI*	Size limit	Fair

[1] Compared against Palau Domestic Fishing Laws 2012 and RPPL 9-50 (2015 Amendment).
[2] *Basis for Grade:* Good = Complete closure or 3+ restrictions; Fair = 1-2 restrictions %; Poor = No additional restrictions.
[3] Total number of Poor or Fair indicators for the species or type, among Indicators 18-28. Most indicators were Poor. NI means those species that were not assessed or have no information (e.g. complete ban on Maml and Kemedukl means no fisheries-dependent data).

SDG 14.5.1

SOE Indicator 37. Coverage of Protected Areas in relation to marine area

This indicator considers all nearshore marine areas, including mangroves, reefs, seagrass beds, and other nearshore habitats. Indicator 15 only considered coral reefs. There are significant differences in estimated area between the 2017 and 2019 SOE reports. In particular, PALARIS has updated records to include actual measurements of mangrove, whereas previous reports used estimates (e.g. the 2015 PAN Report). Thus it is hard to tell what the effect from mangroves is. Otherwise, protected area coverage of nearshore marine areas, both as restricted no-take zones and as community-managed zones, continues to increase. However, much of Palau's marine protected area is lagoon (including less productive rubble or sand habitats).

Extent of MPAs has increased. In 2015 there was 1,331 km^2 of nearshore marine area under some sort of management, compared to 1,959 km^2 now. In 2014 there were 35 MPAs, now there are 47 (Figure I37); in 2015, 23 were in PAN, with 25 in PAN now.

	State[4]				Grade	
Type	*km^2*	*Total nationwide*	*%*	*# sites*	*2019*[5]	*Compared to:*
Total nearshore marine managed area (above 100m)[1]	1,959 km^2	2,868 km^2	68%	47[8]	Good	TNC ERA, 40%
Nearshore marine managed area (non-mangrove)[2]	1,943 km^2	2,822 km^2	69%	[9]	Good	
Managed mangrove area	16.5 km^2	49.9 km^2	33%	16	Fair (44%)	Metz (2000), 75%
Total No-Take Marine Protected Area[3]	413 km^2	2,868 km^2	14%	27	Good	Aichi #11, 10%
No-Take Nearshore MPA (non-mangrove)	409 km^2	2,822 km^2	14%		Good	Aichi #11, 10%
No-Take Mangrove MPA	3.9 km^2	49.9 km^2	8%	9	Poor[7] (27%)	MC, 30%[7]
No-Take Coral Reef (Indicator 15)[5]	393 km^2	2,009 km^2	19%	23	Fair[5] (48%)	TNC ERA, 40%
Total nearshore area in PAN (above 100m)	1,217 km^2	2,868 km^2	42%	25[10]	Good	Micronesia Challenge (MC), 30%
Nearshore area in PAN (non-mangrove)	1,214 km^2	2,822 km^2	43%		Good	
No-Take Nearshore MPA in PAN	362 km^2		13%		Fair (43%)	
Mangrove area in PAN	3.8 km^2	49.9 km^2	7.6%	10	Poor (25%)	
No-Take Mangrove area in PAN	3.3 km^2		6.6%	6	Poor (22%)	

[1] All nearshore marine protected areas above 100 meters depth, under any form of officially designated protected area status or management regime; includes sustainable use areas in the Northern Reefs (including Velasco), the Rock Island Southern Lagoon, and elsewhere. Includes IUCN Category VI areas.

[2] Includes lagoon, coral reef, seagrass, and other nearshore marine areas, but does not include mangroves.

[3] Designated as No-Take or as IUCN Categories Ia, Ib, II, III, or IV.

[4] Protected area coverage provided by PALARIS, February 2019, and adjusted to remove redundancy (e.g. so Ebiil is not counted twice as a No-Take zone and as a part of the Northern Reefs managed area). Total mangrove area provided by PALARIS, February 2019 (adding protected plus non-protected to get total). Total nearshore marine area (non-mangrove) provided by TNC (2016) to include all area above 100 meters.

[5] See Indicator 15. Here all reef types have been combined and compared against the lowest ERA Threshold (40%).

[6] *Basis for Grade:* Comparing current to target or goal. Good = >75%. Fair = 40-75%. Poor =<40%.

[7] Targets for mangroves vary, and the most conservative one is used here. TNC ERA recommended a protection threshold of 90%, Metz (2000) recommended 75% protection, and the Micronesia Challenge recommends effective conservation of 30%. With 33% of mangroves under some form of management, Palau is 44% of the way to the Metz target.

[8] There is some redundancy in this number, as it includes No-Take MPAs within larger managed areas. It is better thought of as "number of designations"

[9] Many sites have mixed habitats.

[10] 22 of the 25 sites in PAN are no-take (includes mangrove and non-mangrove habitats).

Figure I37. Map of protected areas in Palau (2019).

SDG 14.5.1

SOE Indicator 38. MPA Management Effectiveness: Ecological impact on nearshore fisheries

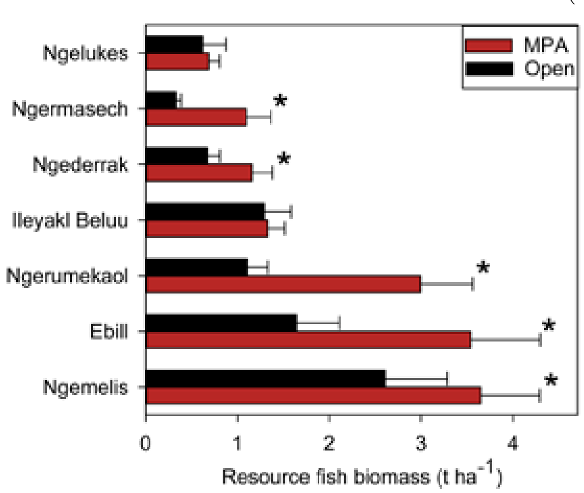
Effectiveness is influenced by size, shape, age, movement of individual species, and level of protection, and "Fully protected areas have... much greater conservation benefits compared with areas under lesser levels of protection" (Friedlander et al. 2017). Indicator 36 shows that 27 out of 47 MPAs are no-take areas; a total of 14% of nearshore area.

In a meta-analysis of seven no-take MPAs and their nearby reference sites, ranging in size from 0.4 km^2 to 40.3 km^2, Friedlander et al. (2017) concluded that the majority were effective at conserving fish biomass relative to reference sites (Figure I37a). Larger MPAs contained higher abundance and nearly twice (2x) the overall biomass (5x for piscivores, Figure I37b) than smaller MPAs. They concluded that because there was little difference in benthic habitat, the difference was due to protection status.

The 2017 SOE gave marine protected areas a Grade of "Fair" because 60% of sites had good ecological scores (the follow-up meta-analysis had not yet been completed for 2016 surveys). It appears that MPAs continue to have mixed effectiveness, with influences from size and management.

	State					**Grade**[1]
Site and Size	*Habitat*	*Coral or Seagrass Cover*	*Fish Biomass*	*Fish Abundance*	*Macro-Invertebrates*	*2019*
Ngermedellim, Melekeok[2] 0.43 km^2	Seagrass	• Higher inside MPA	• No recorded commercially important fish		• Only 1 clam	• Healthy seagrass. • Productive. • Recovering (typhoon).
	Reef flat	• Lower inside • Increasing	• Slightly Higher inside	• Higher inside • Declined (2015)	• More inside	
Teluleu, Peleliu[3] 0.76 km^2	Seagrass	• Lower inside MPA • Declining	• Higher inside • Highest of all seabed MPAs	• Higher inside • Higher diversity inside	• Low Abundance	Protection benefits fish populations
Iuaiu, Angaur[4] 1.11 km^2	Seagrass	• Higher inside MPA • Higher than reef	• Higher inside MPA • Increased (2014)	• Same inside, out • Higher than reef area	• Same in/out • Low Abundance	• Seagrass thriving. • Reef not thriving, Lower & declining fish. • Beneficial for clams. • No management plan.
	Reef flat	• Lower inside MPA	• Much Lower inside MPA	• Lower inside • Declined (2014)	• Many More inside	
Ngemai, Ngiwal[5] 2.32 km^2	Seagrass & Flats	• Lower inside MPA	• Lower inside • Low overall	• Lower inside • Low overall	• Declined by factor of 57	• After 10 years of protection, not benefitting fish. • Likely poaching.
	Fore reef	• Same inside, out • Stable	• Lower inside MPA	• Lower inside MPA	• More inside • Very few	
Ngemelachel-Ngederrak (Lighthouse), Koror[6] 5.88 km^2	Reef	• Coral cover recovery on areas of hard substrate; no recovery on rubble • Limited recovery on north end • Recovery started on south end, many small colonies • Cover at Lighthouse recovering well, at 29% • Parrotfish and Surgeonfish populations Increasing at Lighthouse Reef				Profound recovery.

[1] *Basis for Grade:* Subjective, depending on assessment conclusions in the source document.
[2] Marino et al. (2018-Ngermedellim)
[3] Gouezo et al. (2018-Teluleu)
[4] Marino et al. (2018-Iuaiu)
[5] Gouezo et al. (2018-Ngemai)
[6] Mumby et al. (2018)



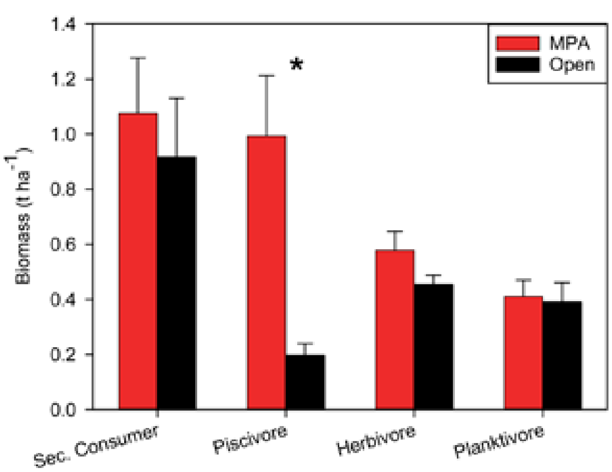


Figure I37a (*left*). Comparison of resource fish biomass (t/ha, mean ± standard error) inside and outside MPAs. From Figure 3 in Friedlander et al. (2017). Figure I37b (*right*). Biomass (t/ha, mean ± standard error) by fish trophic groups and management (open to fishing and MPA). From Figure 6 in Friedlander et al. (2017). * *Asterisk identifies significant differences between MPA and adjacent open area.*

SDG 14.5.1

SOE Indicator 39. MPA Management Effectiveness: Perceived Socioeconomic and cultural impacts

How community members perceive MPAs varies wildly. PICRC conducts socioeconomic monitoring of MPAs, and asks about perceived benefits. Nine surveys completed in 2016 to 2019 were averaged below. The majority of respondents did not perceive any change due to the MPA; for all indicators there was a larger percentage of respondents who perceived increased (desirable) impacts. The highest percentage of respondents reported that they strongly agree with the statement that MPAs provide environmental benefits. Fewer respondents agree that MPAs provide livelihood or economic benefits, with even fewer who agree that MPAs provide cultural or spiritual impacts. Only half of respondents strongly agreed that benefits from MPAs were provided equitably (Figure I38).

State (Average and Range, N=9)[1]					Grade[6]
Perceived Impact on:[2]		*Increased*[3]	*No change*	*Decreased*[3]	
Quality of marine environment	Average	16%	66%	7%	Fair
	Range	0-42%	25-93%	0-25%	
Abundance of fish and invertebrates[4]	Average	15%	63%	10%	Fair
	Range	0-35%	26-94%	1-32%	
Size of fish and invertebrates[4]	Average	13%	65%	9%	Fair
	Range	0-35%	44-94%	2-31%	
Availability of food from fish and invertebrates[4]	Average	13%	63%	11%	Fair
	Range	0-35%	26-95%	2-31%	
Spiritual and cultural amenity	Average	8%	69%	5%	Fair
	Range	0-33%	50-95%	0-15%	
Level of Agreement with:		*Strong*[5]	*Moderate/Little*[5]	*None*	
MPA provides livelihood benefits	Average	54%	29%	8%	Good
	Range	23-92%	5-71%	1-21%	
MPA provides economic benefits	Average	60%	24%	5%	Good
	Range	25-91%	4-69%	2-14%	
MPA provides cultural/spiritual benefits	Average	48%	25%	10%	Fair
	Range	23-79%	8-71%	3-34%	
MPA provides environmental benefits	Average	67%	22%	3%	Good
	Range	23-90%	6-72%	0-8%	
MPA provides equal benefits	Average	50%	24%	15%	Fair
	Range	22-78%	9-71%	2-64%	

[1] Socioeconomic surveys from 2016 to 2018 for Kayangel, Ngaraard, Ngiwal, Melekeok, Ngchesar, Ngatpang, Airai, Peleliu, and Angaur.

1. Marino and Jonathan (2018-Angaur)
2. Marino and Jonathan (2018-Melekeok)
3. Marino et al. (2017-Ngatpang)
4. Marino et al. (2017-Airai)
5. Koshiba et al. (2016-Kayangel)
6. Koshiba et al. (2016-Ngchesar)
7. Koshiba et al. (2016-Ngiwal)
8. Koshiba et al. (2016-Peleliu)
9. Koshiba et al. (2016-Ngaraard)

[2] In two separate part of the Socioeconomic surveys, interviewees were asked about the impact of the MPA on Livelihood factors and their level of Agreement with Attitudinal Statements; not all are presented here.

[3] Values are condensed. "Increased" includes sum of respondents who answered "Greatly increased" and "Somewhat increased." "Decreased" sums for "Greatly" and "Somewhat" Decreased.

[4] This includes the range across two different livelihood factors which were presented separately (e.g. Abundance of fish and Abundance of invertebrates).

[5] Values are condensed. "Strong" includes sum of respondents who answered "Very Strongly Agree" and "Strongly Agree." "Moderate/Little" sums for "Moderately Agree" and "Agree a Little". "None" is the percent of respondents who answered "Do Not Agree."

[6] *Basis for Grade:* Subjective. *Perceptions:* Those with 10% or more who perceived a decline were graded "Fair." *Agreement:* Those graded as Good have total agreement above 80% and disagreement below 10%. Those graded as Fair have disagreement above 10%.

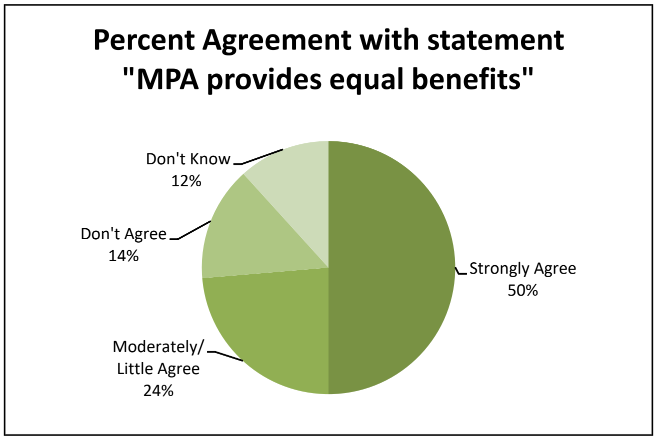


Figure I38. Perceptions of equitable benefits from MPAs.

SOE Indicator 40.

Aquaculture Production

Aquaculture production is relatively low and below demand, with much produced for non-food use. The investment in the Marine Mariculture Demonstration Center will increase capacity to 1,000,000 clam seedlings per year, up from 200,000. Total production appears to be increasing (Figure I40).

Dominated by Milkfish and Giant Clam, there is some production of coral, mangrove crab, grouper (Gillet 2016), and shrimp (BBP 2017). Palau-based company Biota successfully cultures ornamental marine aquarium fishes for export, and has successfully aquacultured Kemedukl from the egg (a world first) as well as snappers and other food fishes. They released large numbers of rabbitfish for restocking in the past two years (Colin 2019).

Type (2017)	*Pieces*[1]	*Value*[1]	*%Total Value*
Milkfish	468,900	$97,780	45%
Giant Clam (Food)	12,594	$100,752	46%
Shrimp	913	$10,261	5%
Reef fish	4,156	$9,420	4%
	# farms	*# Food*	*#Export/bait*
Giant Clam Farm	60[3]	60	10[2]
Milkfish Farm[2]	4	3	1

[1] BBP (2017). Clams calculated at $8/clam.
[2] Gillet (2016). [3] PMDC worked with 60 clam farmers in 2017.

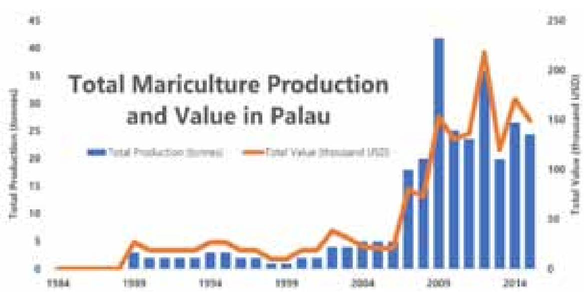


Figure I40. Aquaculture trends (p. 10 in Barfield et al. 2017).

SOE Indicator 41.

Fishery Production from small-medium businesses

SDG 14.b.1

Assuming that all nearshore fishery production is conducted by small to medium businesses, in 2014 nearshore fisheries accounted for 11% of Palau's total fishery production in dollars and 22% of total fishery production in metric tons (Gillet 2016 in CEA 2016). In the tuna industry, a single, locally-based pole-and-line vessel represented 3.5% of the value from locally-based longline fishing (in 2014).[1]

	mt	*%*	*Value*	*%*
Nearshore commercial and subsistence catch	2115	21%	$6,500,000	11%
Offshore locally based	3987	39%	$31,471,000	55%
Offshore foreign based	4017	40%	$18,555,070	33%
Freshwater	1	0%	$10,000	0%
Aquaculture	22	0%	$285,000	1%
TOTAL	$10,142		$56,821,070	
Locally-based longliner			$6,219,200	97%
Pole-and-line vessel			$225,000	3.5%

SOE Indicator 42.

Sustainable Fisheries as Percent of GDP

SDG 14.7.1

With no official definition of "Sustainable" Fishing, this can only be a broad estimate. Indicator 36 shows that at least 79% of Palau's nearshore fish species are being overfished, and thus not fished sustainably. In 2014, Bigeye Tuna were being overfished (above MSY), which represented half of Palau's tuna catch.[1] Production value of fisheries to GDP was estimated at 4.6% in 2014 by Gillet (2016). Removing 79% of the value for nearshore catches and 50% of offshore catches (from table on page 27 of CEA 2016), the 2014 production value of Sustainable Fisheries to GDP was thus 1.8%.

[1] 2017 SOE. Offshore Fishery status continues to evolve. See Indicators 43 and 44.

Addressing Pressures, Risks, and Gaps reported in the 2017 SOE

Most of the pressures, unmitigated risks, and gaps reported in the 2017 SOE are still present.

The greatest effort has been from initiatives to increase offshore fish consumption, with hoped-for reductions in nearshore fish consumption, via the Domestic Fishing Zone of the Palau National Marine Sanctuary (PNMS). This has included national awareness campaigns, and offshore fish appear to be more in demand and prevalent in stores (with some grocery stores even advertising when tuna are available).

Extent of Marine Protected Area has increased, although key habitats for fisheries are still protected in too few no-take zones, and many are too small.

The following pressures and gaps reported in the 2017 SOE are still prevalent:

- Still lacking adequate fisheries laws and regulations.
- BMR's capacity (funding, personnel, mandate) to monitor and manage nearshore fisheries is still low.
- Nearshore fisheries (fish and invertebrates) still exported via passenger flights.
- Understanding of harvest totals and destinations is still low.
- Information on nearshore fisheries is still widely scattered, across a range of national, international, government, and non-goverment institutions.
- Poaching remains an issue in MPAs and for restricted species.

Overview of Responses and Gaps to Primary Pressures

Palau's nearshore fisheries are in trouble. Of the 39 unique indicators (across location, species, study) assessed for Condition, 69% were Poor. Of the 62 unique indicators with adequate information to see a trend, 49% showed negative (unhealthy/undesirable) trends. There are many unknowns in Nearshore Fisheries: 13 of 61 indicators (21%) had "No clear trend" (or were otherwise marked Gray), whereas only 2 of 18 (11%) were assessed as such for coral reefs.

There has not been a similar, comprehensive response to nearshore fisheries, as there has been for coral reefs, as seen by the numerous gaps that outnumber responses.

Palau must expand its efforts to understand and reduce consumption of nearshore fisheries, and a focus on consuming tuna over reef fish is likely not enough. Responses must also be gender and socially inclusive (e.g. investment in invertebrates has been low).

Primary Pressure	Primary Responses	Key Gaps
Export of Nearshore Fisheries	• Bans on commercial export. • Push for tourists to eat more offshore fish.	• Export of depleted species by passenger flight.
Climate Change	• MPAs and PAN. • Community-based adaptation efforts (but few focused on fisheries). • Monitoring.	• Not enough nearshore MPAs that are large enough to support nearshore fish and invertebrate species. • Selection and location of many smaller MPAs was based on local needs and thus do not consider areas of productivity. • Slow adaptation by fishers to reduced productivity.
Damage to Habitat	• Land Use Planning. • Research and experimentation on habitat restoration. • MPAs to allow for recovery.	• Slow adoption of land-based practices that reduce sedimentation.
Overfishing	• MPAs and PAN. • Size limits, Seasonal and Species Closures, Export bans, Gear restrictions. • PNMS (and shift towards tuna consumption). • Investment in Aquaculture. • Community and NGO-driven Coops and Sustainable Fisheries Partnerships.	• Most MPAs have only moderate impact on conserving or increasing fishery production; prevalence of small MPAs reduces impact of nearshore MPAs on fisheries. • Fishery species with signs of depletion are poorly regulated. • Most species do not have size limits, and existing size information (used voluntarily) is inadequate for most species. • Majority of research is based in Koror. • Majority of research has focused on men. • Inadequate monitoring and feedback during open seasons, especially for invertebrates. • Possible undervaluation and low pricing of fishery species, with little tracking of harvests and prices. • Signs of poaching in MPAs, during closed seasons, and of restricted species, with inadequate enforcement. • Palau's Open Access system is a driver of overfishing. In particular, Urban and wealthy fishers access fishing grounds further and further away from population centers. • There are few User Fees or Permits to use or access fishery resources.
Gaps in information, laws, regulations, and investment	• Nationwide projects to review laws and regulations (e.g. GEF6) • Newer National government initiatives to tie budgets to information (e.g. Sustainable Development Goals and System of Environmental-Economic Accounting). • Academic, Semi-government, and NGO-driven research on fisheries. • Investment into aquaculture. • Investment into PNMS.	• National government has invested in MPAs, but not directly in managing nearshore fisheries. NGOs (including global NGOs), Semi-government, and Communities have taken on most fisheries work, and BMR is underfunded. Total investment of 2.8% of fisheries value is below global average of 6%. • Few population estimates and thus no catch limits. • Old data on harvest amounts; little information on destination of harvested fish. • Much less research into invertebrates and non-Reef habitats.

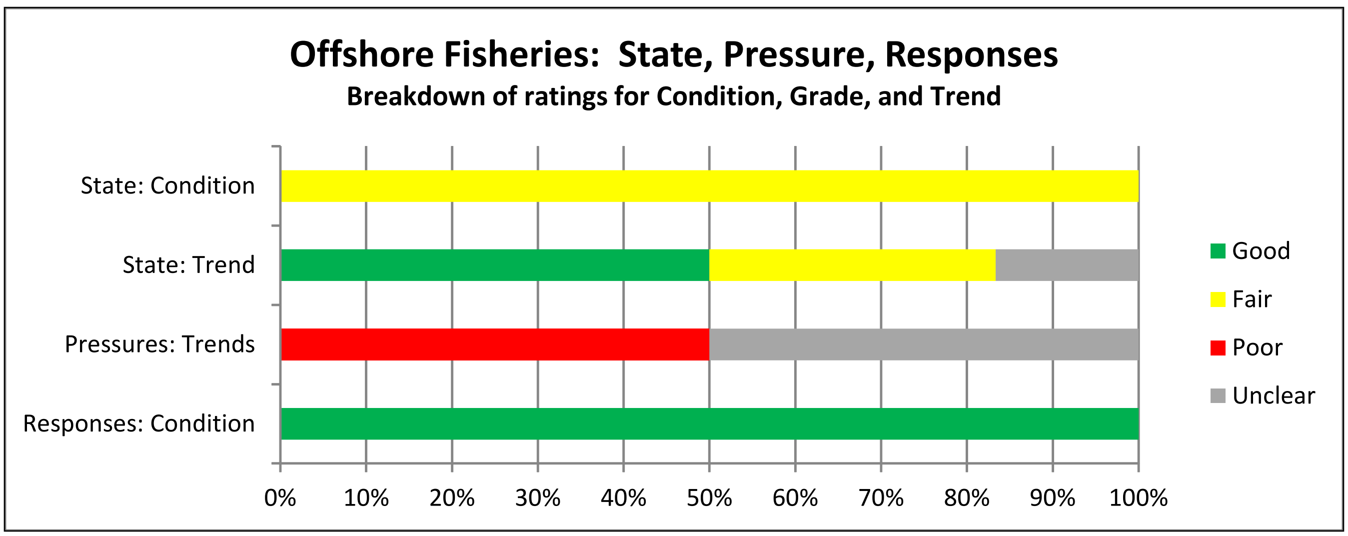
Photo © Shutterstock/Rich Carey

Offshore Fisheries

Information for this section was kindly provided by the Bureau of Oceanic Fishery Management (MNRET) and Conservation International. Additional information was found in published technical reports and journal articles.

State, Pressures, and Responses for Offshore Fisheries

Palau's Offshore Fisheries are in Fair condition, in relation to stock assessments for the entire Western and Central Pacific, but appear to be improving. Pressures from climate change are expected to get worse; there is much that is unknown. Palau's overall response has been good.



Figures for Indicator 43, Offshore Fishery Catch *(See next page).*

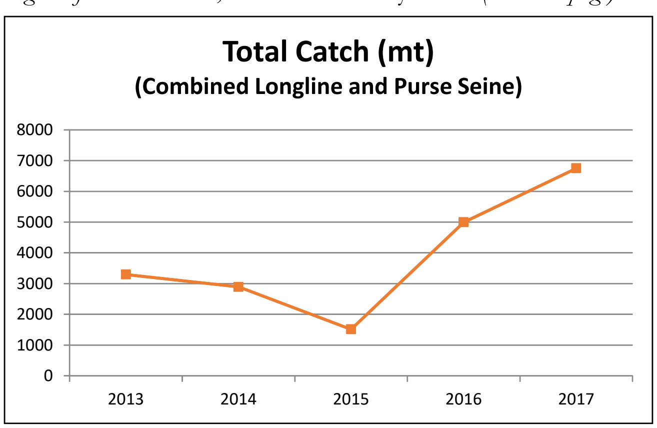


Figure I43a. Combined tuna catch, all fish.

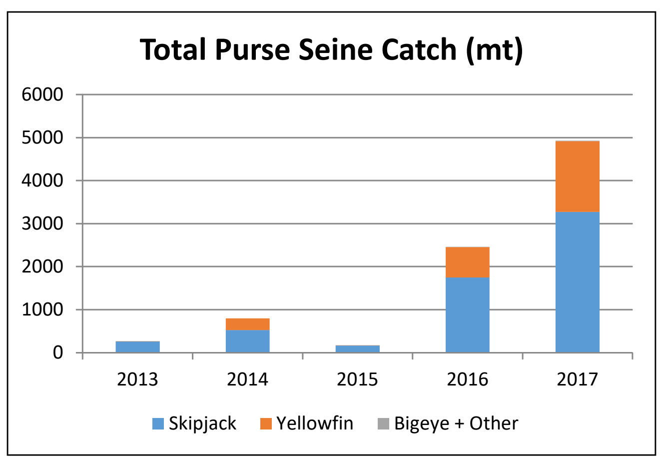


Figure I43b. Total Purse Seine Catch, by year and fish.

SDG 14.4.1

SOE Indicator 43. Offshore Fishery Catch

2016 and 2017 saw notable increases in tuna catch (Figure I43a), most coming from Purse Seiners (I43b), catching Skipjack and Yellowfin (Figure I43c). The reason for the jump is not clear; the number of licensed Purse Seiners in Palau has been stable (Indicator 44). More Purse Seine effort was concentrated in the Western part of the Western and Central Pacific in 2017 (Williams and Reid 2018), and distribution of stock may have been influenced by climatic conditions. However, both Skipjack and Yellowfin Tuna stocks have relatively pessimistic recent stock assessments. Catch of Bigeye has decreased in Palau (Figure I43d), and the formerly overfished stock appears to be improving in the Western and Central Pacific.

	State		**Trend**	**Condition**	**Change**
Fish	*Average 2010-2014*[1]	*Average 2013-2017*[2]	*Comparing time periods, and 2013-2017*	*2019 SOE*	*2017 SOE*
Bigeye Tuna	1,700 mt/yr (longline)	1,300 mt/yr (longline)	Decreased	Fair[3]	Increasing / Poor
Yellowfin Tuna	730 mt/yr (longline)	750 mt/yr (longline)	Stable	Fair[4]	No Trend / Fair
Skipjack	840 mt/yr (purse seine)	1,200 mt/yr (purse seine)	Increased	Fair[5]	No Trend / Good

[1] Bureau of Oceanic Fishery (2015) in 2017 SOE.

[2] Calculated from Oiterang and Sisior (2018); See Table 1.

[3] *Basis for Condition:* The most recent stock assessment of Bigeye Tuna (McKechnie et al. 2017) provides a more *optimistic* assessment of Bigeye stock. Spawning potential of biomass is above 20% in most models, and 2012 saw a large recruitment event. Despite a substantial decline in Bigeye Abundance in the Western and Central Pacific, they conclude that fishing is likely below that for Maximum Sustainable Yield (MSY). Given the decline in catch in Palau of 24% and the improved stock assessment, the Condition is upgraded to "Fair." Both the Trend and the Condition have improved from the 2017 SOE.

[4] *Basis for Condition:* The most recent stock assessment of Yellowfin Tuna (Tremblay-Boyer et al. 2017) provides more *pessimistic* stock status estimates for the Western and Central Pacific. Most estimates suggest that fishing pressure is below that for MSY, but there has been a continuous reduction in biomass. However, Yellowfin Tuna saw a large recruitment event in 2012. Because the catch has been stable in Palau, and because the Pacific catch is still above that for MSY, the Condition is maintained as "Fair." A stable Trend is now visible.

[4] *Basis for Condition:* The most recent stock assessment of Skipjack Tuna (McKechnie et al. 2016) concludes that the (formerly robust) fishery may be approaching MSY in the Western and Central Pacific, although is still below. The Skipjack Fishery is close to its target of 50% spawning biomass, and saw a large recruitment event in 2012. Skipjack catch has increased significantly in recent years, with 2017's Palau catch the highest between 2010 and 2017. Because of the increasing catch and the declining stock assessment, the Condition is downgraded to "Fair." The Condition in the 2017 SOE was Good (due to lower catch and a more robust fishery); a stable Trend is now more visible.

Table 1. Tuna Catch, 2013-2017 (Oiterang and Sisior 2018). All in Metric Tonnes (mt)

	Bigeye (mt)		Yellowfin (mt)		Albacore	Skipjack	Other (mt)				
Year	*Longline*	*Purse Seine*	*Longline*	*Purse Seine*	*Longline*	*Purse Seine*	*Longline*	*Purse Seine*	*Total Longline*	*Total Purse Seine*	*Total (mt)*
2013	2021.24	2	765.82	3	73.35	256	175.66	0	3036.07	261	3297.07
2014	1401.75	0	603.97	276	2.06	523	86.51	0	2094.29	799	2893.29
2015	668.65	0	612.63	1	9.66	168	51.07	0	1342.01	169	1511.01
2016	1159.09	2	1250.33	704	5.66	1748	123.31	3	2538.39	2457	4995.39
2017	1211.14	6	504.9	1648	2.47	3270	105.62	4	1824.13	4928	6752.13
Average[1]	1292.37	2	747.53	526.4	18.64	1193	108.43	1.4	2166.98	1722.8	3889.78
Average[2]	647.19		636.97		18.64	1193					

[1] By type of fishing. [2] By fish.

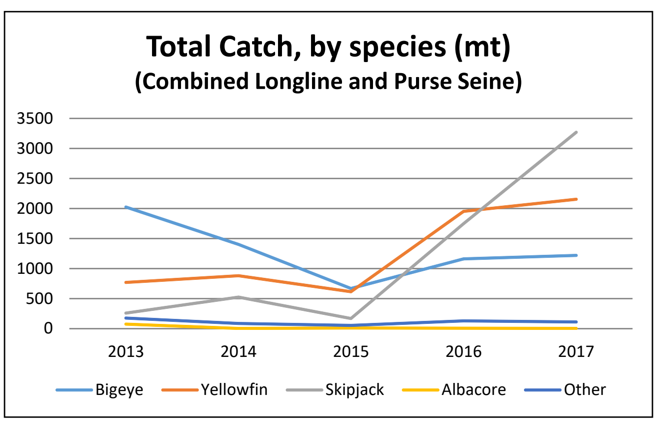


Figure I43c. Total Catch, combined by type, per fish.

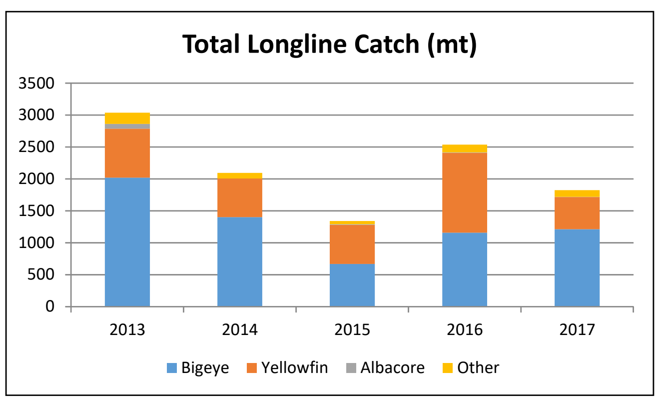


Figure I43d. Total Longline Catch, by year and fish.

SOE Indicator 44.

Fleet Size and Composition

SDG 14.4.1

The size of the foreign fleet (foreign- and locally-based) has been steady (Figure I44a). In 2017 MNRET licensed two vessels as part of a new domestic fleet (formerly Vanuatu vessels) under the PNMS. 37 longline vessels were licensed or chartered to operate in Palau's EEZ: the two Palau Vessels and 35 Chinese-Taipei flagged vessels. Catch from the Palau National vessels represented 3% of the total catch and 5% of vessels (Figure I44b), set here as a baseline (All data from Oiterang and Sisior 2018).

In the 2015 Census, there were 437 Households who engaged in offshore fishing. 306 were urban, 131 were rural households.

Year	*Longline (Foreign)*	*Purse Seine (Foreign)*	*Pole and line (Palau)*	*Longline (Palau)*	*Total Licensed Vessels*
2013	76	5	1		82
2014	52	21			73
2015	51	30			81
2016	57	30		0	87
2017	58	32		2	92

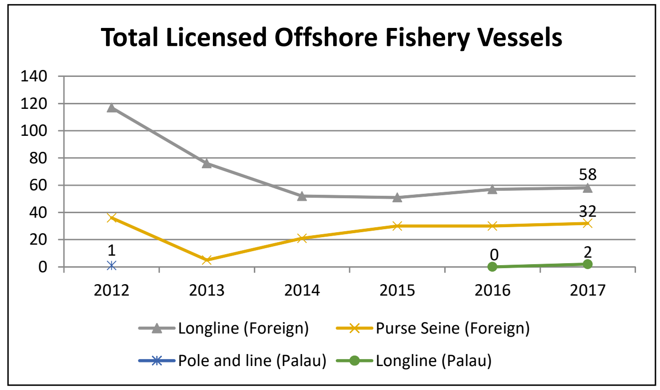


Figure I44a. Total Licensed Vessels

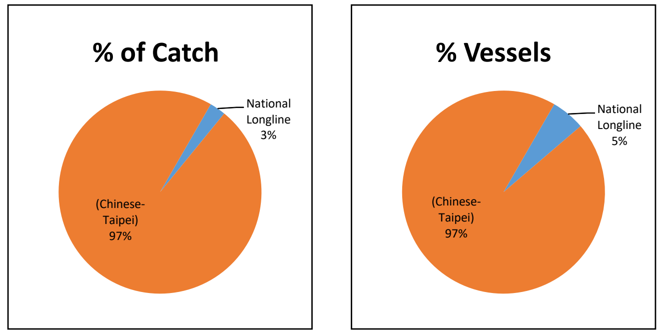
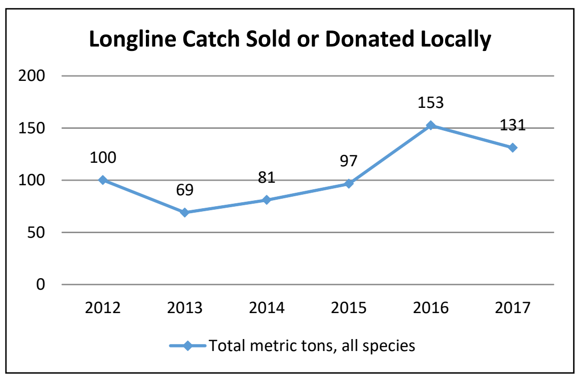
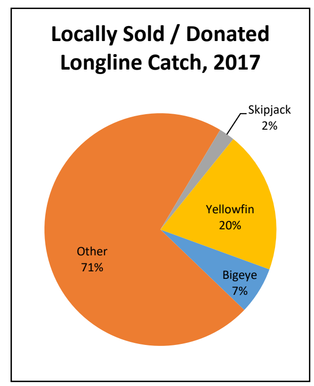


Figure I44a. Percent of catch and vessels, national vs. foreign fleet.

SOE Indicator 45. **Local use of offshore catches**

Local use and supply appears to be increasing. In addition to longline catches, artisanal fishers and tournament participants contribute another ~100 mt/yr. ~40-50% goes to restaurants and 3-4% (~5 mt/yr) is exported by passenger flight (Gillet 2016). In 2016, an average of 700 lbs/month of tuna was processed through the Koror fish market (Lindfield 2017), the equivalent of 4 metric tons.





Figures use data from Oiterang & Sisior (2018) and DOFM (2017).

SOE Indicator 46. **Offshore Fishery Bycatch**

The Nature Conservancy (2018), using data collected by the Palau government, found that one-third of the catch of locally based pelagic longline tuna vessels was made up of unwanted species, ranging from sharks to sea turtles.

Data on bycatch is poor. In 2016 there were 8 Trips with an Observer, in 2017 there were zero (0) (Oiterang and Sisior 2018). 179 individual animals (sharks and turtles) were observed as bycatch on those trips, with a mortality rate of at least 22%.

Observer Trips	*2013 (1 trip)*[1]	*2014*[1]	*2015*[1]	*2016 (8 Trips/64 Trip Days)*[2]			*2017*[3]
Bycatch species and status	*Dead*	*Dead*	*Dead*	*Alive*[2]	*Dead*	*Unknown*	*Discarded*
Thresher Shark				0	1	0	11
Blue Shark				41	6	1	598
Bigeye Thresher				1	3	0	
Silky Shark				82	27	0	1839
Olive Ridley Sea Turtle	1	0	0	13	2	0	
Green Sea Turtle	0	0	0	1	0	1	

[1] Bureau of Oceanic Fisheries (2016).
[2] Division of Oceanic Fishery Management (DOFM 2017). "Alive" combines categories for Discarded Alive, Cut Free, and Escaped, as observed by Observers. There were no seabird interactions observed.
[3] Oiterang and Sisior (2018). There were no observers, so data is from longline logsheets.

Overview of Pressures on Offshore Fisheries

Decline in Stock due to Climate Change	Illegal, Unreported, & Unregulated (IUU) Fishing	Undervaluation
Indicators 47	Indicator 48	Indicator 49

Climate Change Pressures: Acidification, Ocean Temperatures

SOE Indicator 47. Declining Offshore Fishery Productivity

Abundance of tuna in Palau's EEZ is expected to decline by 25% in the next few decades due to climate change (Conservation International 2018).

Models project that there will be significant changes in the distribution of Skipjack, Yellowfin, and Bigeye Tuna by 2050. Projected changes include a strong eastward shift in the distribution of Skipjack and Yellowfin Tuna, and a weaker eastward shift in the distribution of Bigeye Tuna, resulting in reduced abundance of these species in Palau's EEZ (and that of other western Pacific Island countries).

Conservation International (2018) predicts that Palau will see a decrease of $1.6 million in licence revenue from the purse-seine fishery, in 2050 relative to 2016, due to the effects of climate change on the combined biomass.

	State[1]	Trend
Tuna species	*Projected % change in biomass by 2050*	*Projected 2018-2050*
Skipjack	-28%	Decreased
Yellowfin	-12%	Decreased
Bigeye[2]	+4%	Increased
Combined	-24%	Decreased

[1] Conservation International (2018; citing Senina et al. 2018 and Moore et al. 2018)
[2] Lehodey et al. (2011) predicted Bigeye would decrease in the short-term by 4% by 2035 and in the long-term by 11-45% by 2100.

SOE Indicator 49. IUU Fishing

SDG 14.6.1

There has been no comprehensive study on Illegal, Unreported, and Unregulated (IUU) fishing in Palau's EEZ (for both offshore and nearshore fisheries). According to the World Ocean Review (2013), in the Western Pacific, IUU fishing accounts for 34% of total catch.

Several actions have been taken: The Coral Reef Research Foundation has begun work on an interdisciplinary assessment to identify and quantify IUU fishing in Palau; Palau has expanded its innovative monitoring and compliance programs through the PNMS as part of its national plan of action (NPOA) to combat IUU, and Palau ratified the 2009 FAO Agreement on Port State Measures.

Models also project an increased abundance of tuna in high seas areas, resulting in a larger proportion of the catch of each species being made in international waters (See Table 1).

Table 1. Projected changes in biomass of tuna, by 2050, in areas of International Waters adjacent to Palau's EEZ.[1]

	Projected % change in biomass by 2050			
Location	*Skipjack*	*Yellowfin*	*Bigeye*	*Combined*
North of Palau (I1)	-52%	-19%	0%	-43%
South of Palau (I3)	+21%	-7%	+3%	+15%

[1] Conservation International (2018; citing Senina et al. 2018 and Moore et al. 2018).

SOE Indicator 49. Undervaluation

Offshore Fishery resources are likely undervalued. Since 2008 Palau had been charging $0.35 per kg of tuna exported by the locally-based longliners. The estimated tax received in 2014 was $500,000. Exports via luggage at the airport are also charged a tax, ranging from $5 for citizens to $25 for commercial export (per declaration) (Gillet 2016). The $0.35/kg export tax was much lower than that recommended by a Tax Review Task Force in 2008: $0.85/kg (Rhodes et al. 2011). Internal pricing is also set too low.

Total value of tuna harvested by the locally-based longliner fleet in 2014 was $31.5 million and $18.5 million for the foreign-based longliners and purse seiners. The contribution of the locally-based longliner fleet to Palau's GDP was $6.2 million in 2014 (Gillet 2016). On average Western and Central Pacific countries only receive 5% of the value of landed tuna catch (Rhodes et al. 2011). The value of fish caught by the single Pole-and-Line vessel was estimated at $375,000 in 2011 (Gillet 2016). Due to high demand from the tourism industry, prices for tuna have increased from $3.75/kg in 2011 to $5.60/kg at the JR5 Central Fish Market. Using these prices, the estimated value of tuna brought in by the Pole-and-Line vessel is $560,000. Artisanal catch (~94 mt/yr in 2017) was worth an additional $528,000 per year, or approximately $1,200 per fishing family.

Overview of Responses and Gaps to Primary Pressures

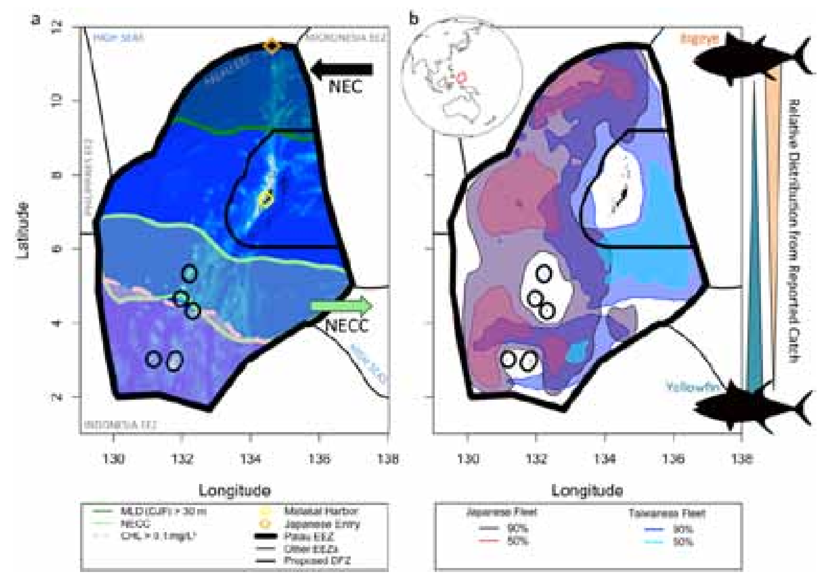
Only three unique indicators (for species) were assessed for Trend and Condition; the majority were Fair. Full implementation of the PNMS and Domestic Fishing Zone by 2021 will likely impact the Condition and Trend of indicators.

Palau is operating under a Tuna Fisheries Strategic Plan 2017-2021 (MNRET 2017) that addresses multiple aspects of offshore fisheries, including Bycatch and Mortality, National food security, and Positive social and economic returns.

Pressure	Primary Responses	Key Gaps
Decline in stock due to Climate Change	• Implementation of the Palau National Marine Sanctuary (PNMS), including a ban on fishing in 80% of Palau's EEZ. • International partners, like Conservation International and UNDP, are helping Palau access funding through bilateral and multilateral mechanisms • Research to understand stock structure.	• The domestication piece appears to be progressing slowly. • In early 2019 there was political pressure to delay implementation of the PNMS.
IUU Fishing	• Research, such as CRRF's efforts to quantify IUU; and development of a pressure prediction system (see Cimino et al. 2019, below). • Implementation of a Monitoring, Compliance, and Surveillance (MCS) Plan. This includes partnerships to use technology to monitor the EEZ and enforce compliance. • The Northern Reefs Project is modeling improved policies, monitoring, and enforcement for both nearshore and offshore areas, in the 12-mile territorial waters zone (Bigue and Rosero 2014).	• The extent and impact of IUU fishing is not well understood. • Adequately enforcing the EEZ remains a challenge.
Undervaluation	• Research: PICRC research indicates that tourists are willing to pay $10 more for local, sustainably sourced tuna (Golbuu 2019 quoted in Pojas 2019). • Ongoing work by MNRET to develop a comprehensive Fisheries Policy that would address taxation, incentive, ownership, equity, etc.	• There are still many unknowns about the economic impacts of the PNMS, and whether it will increase prices.

Cimino et al. (2019) revealed the spatial, temporal, and interannual variation in fishing efforts in the EEZ, and found that oceanic conditions were a predominant predictor of fishing effort. Their models lay the foundation for a forecast system that can be used to predict and combat IUU fishing.

Figure, right: The Palau EEZ has distinct biophysical characteristics that influence fishing patterns. (a) The mean region with the eastward flowing North Equatorial Counter Current, the region influenced by the westward North Equatorial Current, high Chlorophyll-a concentrations and deep winter (December, January, February - DJF) mixed layer depths are shown. Bathymetry is shown in the background. (b) Regions fished by the Taiwanese and Japanese tuna longline fleets, with catch being mostly bigeye in the north and yellowfin in the south. The kernel density estimate for the 90% and 50% contour represents the range and core of fishing locations.



This figure is used under the Cimino et al. (2019) article's Creative Commons Attribution 4.0 International License. See bibliography for full citation. Figure sourced from https://www.nature.com/articles/s41598-018-36915-x/figures/1. The figure was not changed but the figure caption was edited for length. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.

Addressing Pressures, Risks, and Gaps reported in the 2017 SOE

Palau has made progress in addressing pressures from external forces, with expansion of monitoring and surveillance and implementation of awareness campaigns about the PNMS (including the Palau Pledge).

Several gaps still remain:

- So far there is no estimate of Maximum Sustainable Yield within the 20% Domestic Fishing Zone.
- There is still inadequate monitoring of local (artisanal) offshore fishing, both in terms of harvest and destination/use.
- There were no observers on tuna fishing boats in 2017. Although the PNMS calls for 100% observer coverage by 2020, this is a current gap.

Select Marine Sites & Species

Photo copyright Michael N. Dawson (2019)

Much of the information for this section was kindly written or provided by CRRF (Indicators 50-52). Additional information was found in published technical reports and gleaned from publicly available sources, including websites.

Because marine species and sites vary widely, the state of select marine species and sites varies widely as well. Therefore, this report has not been able to assign a Condition, Trend, or Grade for most of the following indicators. Narrative descriptions provide an assessment of how the indicator is doing, what pressures it faces, and may discuss responses.

State of Select Marine Species & Sites

In general, marine species and sites are trending in ways that are not healthy/desirable: Damage from climate change is expected to get worse; Marine invasive species may be increasing, and are now established in some places; Recreation sites are becoming more overcrowded; Sea Turtles and Dugongs are not well understood, but are definitely being poached despite low populations; and, although local population and threat status is not well known, many of Palau's Endangered Species are declining or not protected.

Pressures on Select Marine Species & Sites

When understood, pressures vary widely, and include a variety of natural and human stressors. The lack of knowledge or monitoring programs for most marine sites and species is a key limitation to understanding or addressing pressures.

Responses for Select Marine Species & Sites

Jellyfish Lake and its unique species are well understood and monitored. Most other marine species and sites discussed here have some sort of regulation or law applied, even if inconsistently. However, compliance and enforcement must be strengthened to stop declines and reduce pressures. Palau's National GEF6 Project was designed to address the lack of central authority on species, and will work to resolve gaps and inconsistencies between partners who work with individual species, especially among enforcement agencies.

Photo by A. Gupta

SOE Indicator 50. Ongeim'l Tketau (Jellyfish Lake)

This section was written by CRRF.

Climate Impacts on Jellyfish Lake

Strong El Niño-related drought and subsequent high lake water temperatures impact Jellyfish Lake. The Coral Reef Research Foundation (CRRF) has been monitoring the environmental parameters and Golden jellyfish population in Jellyfish Lake since 1999. The disappearance of *M. papua etpisoni* has occurred before, the best known instance in 1999-2000 (Dawson et al. 2001), following the 1998 coral bleaching event in Palau, but the lake was not under study during the full 1997/1998 El Niño/La Niña event. The medusae reappeared in 2000 and showed dramatic fluctuations in the estimated population size for about six years, reaching a maximum of ~18 million, thereafter 'stabilizing' to an average of 5-7 million jellies, when 'old time-visitors' agreed the lake was 'back to normal'. Following the medusae recovery, it was learned the number of medusae in the lake at a given time was inversely proportional to the mean water temperature in the oxygenated upper 12 m of the lake: warmer temperatures had fewer medusae and cooler temperatures had more.

The strong El Niño of 2015/2016 caused an extreme drought in Palau, which peaked in April 2016. In December 2015, the *M. papua etpisoni* population started a noticeable decline, reaching zero medusae in May 2016. The extreme drought and eventual rise in lake water temperature is thought to be related to the crash of the medusae population, though the exact mechanism is not yet understood. The lake remained without Golden jellyfish until the start of 2017, had a brief burst of new medusae for a few months, and then died off again. Only at the start of 2018 did jellyfish numbers start to increase, as the lake temperature decreased, so that by the end of 2018 they were approaching one million medusae. While less than 'normal', this number was enough to make visiting Jellyfish Lake a satisfying tourist experience again (Figure I50a).

Jellyfish Population Crash

Golden jellyfish medusae crash resulted from impacts of the strong El Niño and not a result of human actions. The disappearance of the jellyfish in OTM has been a cyclical occurrence (1999, 2016) and is related to extreme changes in climate which occur globally. There is no evidence that urination of thousands of tourists in the lake and presence of sunscreen chemicals caused the disappearance of the Golden jellyfish. Instead, the jellyfish die-off was highly correlated with changes in environmental lake conditions associated with ENSO shifts.

Figure I50a. Jellyfish lake in late 2018. Photo copyright Coral Reef Research Foundation, 2019. Used with permission.

Based on what was learned during the 1999-2000 Golden jellyfish collapse and the careful monitoring of their recovery in Jellyfish Lake, there was high confidence the medusae population would recover as long as 1) the benthic polyps remained abundant and viable and 2) mean water temperature in the upper layers (0-12m) of the lake dropped to a level of ≤31.5°C. In 2018 through early 2019 CRRF's predictions of when the medusae would return were validated.

Threat from Non-Native Species

Non-native species introductions are the major threat to Jellyfish Lake. Introductions of non-native species (that do not naturally occur in the lake) are a major threat to Jellyfish Lake. This includes any plant or animal (or parts) found in the lagoon waters and other lakes, such as shells, sea grass, seaweeds, corals and clams. Non-native species can be introduced into the lake by visitors intentionally, or unintentionally as hitchhikers on gear and equipment. Once introduced, non-native species have the potential to become invasive and impact the lake.

So far, CRRF has documented six non-native introductions into Jellyfish Lake: (1-3) a brown sea anemone, *Exaiptasia pallida* (Figure I50b) and its 2 symbiotic zooxanthellae species, (4) an orange sponge, *Haliclona* sp., and (5-6) an unidentified colonial polyp and its symbiotic zooxanthellae. The brown sea anemone, first spotted in 2003, has since established an invasive population, covering mangrove roots and shallow bottom around the perimeter of Jellyfish Lake. First seen in 2001, the orange *Haliclona* sp. sponge is found in dense patches at different places throughout the lake. The unidentified colonial polyp was discovered in 2014, and small patches were observed along the east and west perimeter; however, a more thorough survey is needed to determine its distribution in the lake.

Moon Jellyfish Return

The reappearance of the Moon jellyfish in 2017 was a surprise. The Moon jelly (*Aurelia* sp. 4) in Jellyfish Lake has been an enigma. The population of the large white medusae was 'always present' since the late 1970's when the first research was done in Jellyfish Lake, until their numbers started decreasing in 2003, with the last recorded observation in 2009. The cause of their disappearance was not understood and it did not directly coincide with the introduction of the non-native sea anemone, *Exaiptasia pallida*, to Jellyfish Lake, as has been suggested.

In 2017, scattered Moon jelly medusae were suddenly found again in the lake and have been increasing in numbers since then. *What happened?* We have never found Moon jelly polyps in Jellyfish Lake, and are not sure of their habitat. It is clear the polyps survived in the lake during the absence of their medusae, but were not producing ephyrae to become medusae. This returns to the typical "boom and bust" strategy of jellyfish in the ocean, and suggests more long-term monitoring of Jellyfish Lake is important to answer many remaining questions.

Jellyfish Lake and Sunscreen

The Precautionary Principle applies to sunscreen in Palau's jellyfish *lakes*. Studies by CRRF found sunscreen compounds in water from Jellyfish Lake and other marine lakes in Palau, as well as in medusae themselves at low levels (CRRF 2017). With the ubiquity of such compounds in daily life and their known use by visitors to the lake, this result is not surprising. At present, however, no effect attributable to sunscreen compounds has been detected and for the moment it is a lesser concern than other threats to the lake(s). The precautionary principle, however, requires action despite the detection of a direct threat and it is suggested sunscreen use by visitors to the lake be reduced or totally eliminated.

Through the Responsible Tourism Education Act of 2018, Palau has banned the importation and manufacturing of "reef-toxic sunscreen" (defined as containing oxybenzone and 10 other ingredients). While at present no detrimental effects of sunscreen on the lake or jellyfish have been documented, enforcement of this law will limit future risks to Jellyfish Lake.

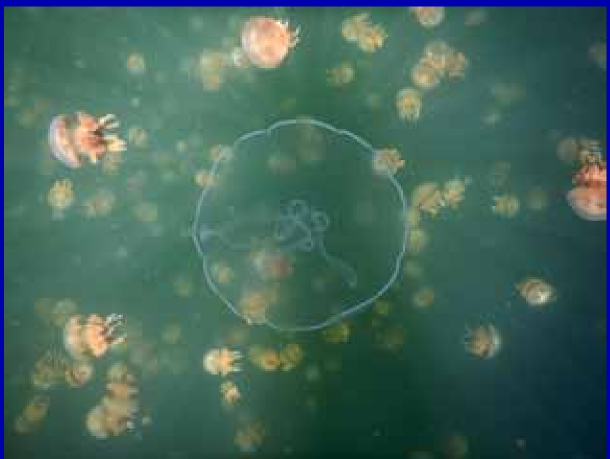
Figure I50b. The non-native brown sea anemone, *Exaiptasia pallida* in Jellyfish Lake. Photo copyright Coral Reef Research Foundation, 2019. Used with permission.

Palau's unique Jellyfish Lakes

This information kindly provided by CRRF.

Palau has over 50 marine lakes, bodies of brackish seawater located inside the karst rock islands, isolated from the surrounding lagoon by land over distances of up to a few km. The lakes have subterranean connections through the brackish ground water that underlies all the rock islands; the cracks and fissures in the island limestone allows tidally-driven water movement to cause the water in the lakes to rise and fall (damped and delayed) with the lagoon tides. Five of these lakes have jellyfish populations of endemic subspecies (one unique to each lake) that are derived from the *Mastigias papua* population which inhabits the lagoon (Dawson 2005).

Only one jellyfish lake, Ongeim'l Tketau (OTM), has the conditions (easy accessibility by boats at all tides, short trail length, moderate vertical climb, usually perennial Golden jellyfish population) to be sufficiently accessible for tourist visits and is currently open to the public. OTM has had as many as ~100,000 visitors making the trek to the lake in a year, with Koror State deriving significant income from permit fees to visit the lake.



Photo, above. The moon jelly *Aurelia* sp. 4 (center) and Golden jellyfish, *Mastigias papua etpisoni* in Jellyfish Lake. Photo copyright Coral Reef Research Foundation, 2019. Used with permission.

Jellyfish Lake has two species of jellyfish (see Photo, below), the Golden jellyfish, *Mastigias papua etpisoni* (an endemic subspecies), and the moon jelly *Aurelia* sp. 4 (Dawson and Jacobs 2001). These jellyfish have two life stages, a tiny benthic polyp (which is seldom seen by visitors) and a large swimming medusa stage, the classic "jellyfish". The population of medusae of *M. papua etpisoni* in OTM has varied greatly over the last few decades. At times of environmental stress there have been no medusae occurring in the lake, but the benthic polyps have always persisted. These polyps produce new medusae when conditions return to "normal" through a process of strobilation, in which baby medusae (called "ephyra") are budded off the end of the polyp and become a swimming medusa.

Jellyfish in the ocean go through seasonal cycles, with medusae being present when conditions are favorable and absent when conditions are unfavorable. This is most obvious in temperate regions, where medusae typically appear in Spring and disappear in Fall, but also happens in tropical populations. When conditions are particularly good, populations may "boom" and be exceptionally abundant; when conditions change, the population "busts" as the over-abundant medusae die, but the polyps survive in a "dormant" state . In some environments, climatic, rather than seasonal, cycles can drive these "boom and bust" dynamics. Thus, when conditions are right, the "boom" part of the cycle can last for decades (as occurs in OTM), but the "bust" population crash can occur when conditions change to sub-optimal. It is believed the OTM *M. papua etpisoni* live only about 6-9 months, and the medusae population must be constantly replaced during the "boom" phase or else it will crash, going to zero in less than a year. During the boom phase, the numbers of medusae in the lake vary with environmental conditions (such as water temperature) and numbers go up and down through changes in the production rates of ephyrae.

Overview of Pressures on Select Marine Species and Sites

Given the wide range of marine species and sites, these are just a few primary pressures.

Climate Change	Invasive Species	Crowding / Overuse	Harvest/ Poaching	Gaps in knowledge
Indicators 50-51	Indicator 50 & 52	Indicator 53	Indicator 54-56	Indicators 52-56

Climate Change Pressures: Stronger Typhoons and Storms

SOE Indicator 51. Damage to shorelines from typhoons and tropical storms

Typhoon Haiyan in late 2013 caused only minor erosion to the islands of Kayangel Atoll, despite its intense winds and high seas. In many respects the islands have started to recover from Haiyan, with some vegetation recovering. The storm berms produced on the eastern shore of Angaur, and to a lesser extent Peleliu, by Typhoon Bopha in 2012 have stablized, moving island(s) shore slightly seaward. Significant vegetation capable helping to stabilize these new shorelines (Casuarina and Scaevola trees) have grown on the storm berms in the past five years. Beaches in the Rock Islands have exhibited some changes, mostly due to movement of sand from the typhoons of 2012 and 2013, but these mostly seem to represent shifts of sand, rather than permanent erosion and loss of sand to deep water.

Figure I51. Storm berms on the east coast of Angaur, formed by waves during Typhoon Bopha in December 2012, have become colonized and stabilized by trees and other vegetation since the storm. Photograph copyright Coral Reef Research Foundation, 2019. Used with permission.

SOE Indicator 52. Marine Invasive Species

CRRF identified 20 introduced marine species (Probable or Possible introduced Hydroids and Ascidians; Colin 2009). Colin (2009) also discussed the unknown status of the introduced *Tilapia* fish and the sea anemone in Ongeim'l Tketau, *Aiptasia* sp., (for a total of 22). After surveys in 2007[1] and a literature review, Campbell et al. (2016) identified 40 marine introductions (introduced, cryptogenic, and potentially introduced species).[2 3]

The invasive sea anemone (*Exaptasia pallida*) in Ongeim'l Tketau has been monitored as part of the overall Jellyfish Lake program (Patris et al. 2012). It has arrived at a somewhat steady state, with the apparent population size changing with water temperature changes, as the anemone has symbiotic algae and can undergo a condition similar to coral bleaching at high temperatures. Even so, the native species diversity and abundance of *E. pallida* do not appear to be significantly correlated (Patris et al. 2019). The sea anemone is now a permanent part of the fauna of Jellyfish Lake and cannot be eliminated (Colin 2019).

The status of other marine invasive species, such as the hydroid *Eudendrium carneum*, has not been determined in recent years (Colin 2019).

Figure I52. *Exaiptasia pallida* cannot be eliminated from Jellyfish Lake. Photo copyright Coral Reef Research Foundation, 2019. Used with permission.

[1] These field surveys, in Campbell et al. (2016), were described as "preliminary" and part of a training course.

[2] The two data sources do not always align (e.g. identification or criteria used to determine if introduced, level of likelihood of introduction, description as pest).

[2] See also the Correction and Update on p. 53.

SOE Indicator 53. Crowding at Marine Recreation Sites

See also Indicator 13 (visited sites had more rubble than non-visited sites). In both 2015 (Otto et al. 2016) and 2016 (Nestor et al. 2017), density of coral fragments were higher at visited sites in the Rock Islands than non-visited sites. Wabnitz et al. (2017) suggested reducing diver numbers per site and year to 5000-7000, noting that the threshold was currently being exceeded by a factor of 13. Poonian et al. (2010) estimated 50,000 dives at German Channel per year, which is 7 to 12 times higher than that recommended for dive sites.

A PICRC survey in 2016 of Japanese tourist perceptions (Miyakuni et al. 2018) found that 53% of survey respondents perceived German Channel as crowded. Across multiple sites, popular snorkeling sites (Paradise, Big Drop off, Fantasy Island) were perceived crowded by 19-30% of respondents, popular diving sites (German Channel. Blue Corner, Blue Hole) were perceived crowded by the 24-53% of respondents, and other marine recreation and water-based sites such as Milky Way were perceived crowded by 20-30% of respondents.

The 2017 SOE graded this indicator as Poor, but here it is graded as Fair, due to new information, not because of reduced impact.

State					**Trend**
Site	*Extent of Crowding*				
Dive Sites	13 times above recommended (2015)[1]				Increased[4]
German Channel	7 to 12 time above recommended (2010)[2]				
	Percent of Japanese Tourists who thought site was crowded[3]				**Grade**
Snorkeling sites	Cemetary Reef 49%	Big Drop Off 30%	German Channel 19%	Fantasy Island 28%	Fair[5]
Dive Sites	Blue Corner 46%	Big Drop Off 33%	German Channel 53%	Blue Hole 40%	
Marine & Water-based Recreation Sites	Long Beach (Omokan) 30%	Long Beach (Kayangel) 25%	Milky Way 20%	Ngardmau Waterfall 22%	

[1] Wabnitz et al. (2017)
[2] Calculated from Poonian et al. (2010)
[3] All values from Miyakuni et al. (2018)
[4] *Notes on Trend*: Comparing values from 2010 to 2015; these values only provide general guidance and do not represent a scientifically valid carrying capacity or absolute value of overcrowding.
[5] *Basis for Grade*: Miyakuni et al. (2018) cite the following from Shelby and Heberlain (1986): "If more than two-thirds of the visitors say that they are crowded, it appears likely that the capacity has been exceeded. If less than one-third senses the over-crowding, the area is probably below the load capacity." Using this threshold, several sites are below capacity, but a few are nearing the point of being above capacity; thus the subjective grade of Fair is assigned.

SOE Indicator 54. Sea Turtles

Pressures

According to Island Conservation (2018), "Turtle poaching [is] on the rise in recent years." However, there is no new available information or data on turtle populations or level of poaching. The 2017 SOE reported that in 2014-2015 60% of surveyed nests in the Rock Islands and in 2016 17% of nests on Ngerkeklau and Ngerchur (Ngarchelong) had been poached. There was evidence of negative impacts from climate change: eggs spoiled by seawater (e.g. from storm surges or rising tides) and nests destroyed by typhoons.

Responses

In 2017 rats were eradicated from Ngeanges Island in the Rock Islands through a partnership with Island Conservation, the Koror State Department of Conservation and Law Enforcement, and Palau Conservation Society (Island Conservation 2018). Given that rats are known to predate on turtle nests, their eradication removes one threat in a location with known nesting Hawksbill Sea Turtles.

In 2018, Palau amended the Environmental Quality Protection Act (Title 24) to established a 10-year moratorium on the harvest or use of any Hawkbill Sea Turtle (with an exceptino for existing toluk). The law included a 2-year phase out on selling of existing turtle products.

SOE Indicator 55. Mesekiu (Dugong)

Pressures

Although fully protected, poaching/illegal hunting has been known to occur. Given their reliance on seagrass habitat, declining seagrass cover (Indicator 32) may pose a growing threat (Siksei 2018). During an permit application inspection, dugong were observed by EQPB at a potential sand mining site (Brooks 2018).

Responses

Studies by the Coral Reef Research Foundation have detailed the relationships between dugong, tides, and benthic habitats in the Malakal/Ngderaak Reef area of Koror. This builds on earlier work for the Palau Dugong Awareness Campaign of 2012-2013 with Mandy Etpison of the Etpison Museum. New work has refined the population estimates, feeding locations, and behavior and social behavior of these coastal marine mammals. A study of the long term changes in dugong habitat (seagrasses) at Ngederrak Reef is presently being completed, providing insights into how the food resources of this population have changed through grazing, storms, and other types of change.

Palau's law to protect Dugong is strong, and enforcement appears to be improving. In 2014 and 2015 there was some enforcement of illegal poaching (Brooks 2018).

14 LIFE BELOW WATER

ABT 12

SOE Indicator 56. Globally & Locally Endangered Marine Species in Palau

Palau's number of endangered species is not known, given few population assessments. Assessments for an updated Palau Endangered Species Act (ESA) List are ongoing for marine species; those included here were from the previous ESA.

A 2016 Country Data Dossier for Aichi Target 12 (Reducing Risk of Extinction; SPREP 2016) identified 23 marine mammals known from Palau; of these 3 are threatened (13%).

The number of endangered fish and invertebrates relative to the total number present in Palau is low, but most have not been assessed, either for local population or for global status.

Several of the globally endangered species in Palau are also declining locally. The majority of these species has some sort of local protection, in the form of laws, regulations, or MPAs; although many are declining and need additional enforcement effort or updated protections (e.g. updated laws or regulations).

There are few known marine endemic marine species (Colin 2009). None of the globally endangered species listed here are endemic to Palau. Palau's known endemic marine species (*Nautilus belauensis*) and the five subspecies of *Mastigias* jellyfish have not been assessed by the IUCN Red List; however all Nautilus species are included in Appendix II of CITES.[4]

		State				**Grade[10]**
Class	*Common name*	*ESA[1]* (Palau)	*Red List[2]* (IUCN)	*Global Trend[2]* (IUCN)	*Palau laws/regulations*	*Palau's responses*
Mammal	Dugong[3] (Indicator 55)	EN	VU	Decreasing	Complete closure	Fair - Needs enforcement
	Blue Whale[3]		EN	Increasing	Marine Mammal Sanctuary (Complete closure)	Good
	Sperm Whale[3]		VU	Unknown		Good
	Dolphins, Porpoises, Whales[3, 4]		Varies	Varies		Good
Marine Reptiles	Hawksbill Turtle[3] (Indicator 54)	TH	CR	Decreasing	10-year moratorium	Fair - Needs enforcement
	Green Turtle[3] (Indicator 54)	TH	EN	Decreasing	Title 24 (regulated by size, season, nesting)	Poor - Harvest allowed, Decline
	Leatherback Turtle[3]	EN	VU	Decreasing		Good
	Loggerhead Turtle[3]	EN	VU	Decreasing		Good
	Olive Ridley[3]	EN	VU	Decreasing		Good
	Kemp's Ridley[3]		CR	Unknown		Good
	Saltwater Crocodile[3]			Unknown	No restrictions	Unclear[5]
Marine Fishes[6] (See also Indicator 36)	Bigeye Tuna (Indicator 43)		VU	Decreasing	Regulated by PNMS	Good
	Kemedukl (Bumphead Parrotf.)		VU	Decreasing	Complete Closure	Fair - Poaching; Needs enforcement
	Maml (Napoleon Wrasse)[4]		EN	Decreasing	Complete Closure	
	Square-tail Coral Grouper		VU	Decreasing	Size, season; local ban	Fair
	Bower's Parrotfish		NT	Unknown	No add. restrictions	Fair
	Thorny Seahorse		VU	Unknown	Aquarium spp. regs.	Fair
	Several species of Sharks, Rays, Mantas[4]		Varies	Varies	Shark Sanctuary & Bilateral Surveillance	Good
Invertebrates[7]	Giant Clam (*T. gigas, T. derasa*)[4]	TH	VU	Unknown	Export ban; exception enables poaching[8]	Poor - Decline / Low (Indicator 20)
	Giant Clam (*Tridacna crocea*)			Unknown		
	Tridacna squamosa, H. hippopus	TH	NT	Unknown		
	Nautilus[4]			Unknown	CITES	Unclear
	Charonia tritonis, Cassis cornuta[9]	EN				
	Several species of *Acropora* coral		NT	Decreasing	Export ban	Fair
	Corals: Black, Blue, Stony, Lace[4]				Export ban	Fair
	Mussels (*Lithophaga lithophaga*)[4]				No restrictions	Unclear
	Sea Cucumbers		Varies	Varies	Export restrictions	Poor

[1] ESA = Palau Endangered Species Act, List of Threatened Species. By order of threat: EN = Endangered, TH = Threatened.

[2] Global IUCN Red List Status as of March 2019. www.redlist.org. Trend as determined by the IUCN Red List as of March 2019. By order of threat: CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened.

[3] CITES Appendix I = Species threatened with extinction. CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), as of March 2019. Palau has many species reservations.

[4] CITES Appendix II = Species not necessarily threatened with extinction, but for which trade must be controlled in order to avoid utilization incompatible with their survival.

[5] Not regulated; population may have increased (SOE 2017).

[6] A 2015 assessment of species in Palau (SPREP 2016) identified at least 15 threatened fishes, but did not distinguish by type (freshwater, marine). There are more species that have not yet been assessed; this should not be accepted as the total number of threatened fish.

[7] A 2015 assessment of species in Palau (SPREP 2016) identified at least 40 molluscs and 106 other invertebrates that were threatened, but did not distinguish by type (terrestrial, freshwater, marine). There are more species that have not yet been assessed; this should not be accepted as the total number of threatened invertebrates. *continued next page*

Overview of Responses and Gaps to Primary Pressures

Because marine species and sites vary widely, the status of select marine species and sites varies widely as well. Lack of knowledge and data is a key missing gap, and there is no central authority on species.

In general, marine species and sites are trending in ways that are not desirable. However, there is some sort of response, ranging from laws to activities, addressing most marine species and sites.

Primary Pressure	Primary Responses	Key Gaps
Climate Change	• Some MPAs (with some mangroves protected) for shorelines protection. • Some land use planning and mapping to identify sea level rise threats.	• Inadequate protection of shoreline. • Slow progress in land use planning and continual development in locations with potential negative climate impacts.
Invasive Species	• GEF6 National Project will address numerous aspects, including identification and mapping, monitoring, compliance, and rapid response.	• Implementation of GEF6 has just started. • Little identification and monitoring of marine invasive species. • Eradication or removal of marine invasives is not possible.
Crowding at Sites / Overuse	• Zones in the Rock Islands. • Closures when needed (e.g. Jellyfish Lake). • New laws (e.g. Sunscreen). • Ongoing research by nonprofits, semi-government, and academia.	• Few to no limits on total visitation. • Inconsistent application of closures and *bul* in times of environmental stress. For instance, Jellyfish Lake was officially under a *bul*, but not officially closed by the Koror State Legislature. Permits were available for purchase even when no jellyfish were visible. • Partnerships and understanding still in development with National and State governments on acceptible visitation.
Harvest / Poaching	• Increasing enforcement capacity through PNMS and PAN. • GEF6 National Project will resolve conflicting regulations and build capacity of Fish & Wildlife.	• Inconsistent enforcement of laws and regulations. • Inadequate monitoring to ensure compliance. • Green Turtles can be legally harvested and used for commercially purposes during open season, despite decline.
Gaps in information	• Nationwide projects to review laws and regulations (e.g. GEF6). • Academic, Semi-government, and NGO-driven research. • Jellyfish Lake is well studied, with established research and training programs.	• No comprehensive approach to species. • Little monitoring of marine species (e.g. no systematic monitoring of turtles or dugong or threatened species). • No Palauan Endangered Species List, or process to determine threat status at the National Level.

Addressing Pressures, Risks, and Gaps reported in the 2017 SOE

Knowledge and monitoring of species is improving, through projects (dugong surveys, and turtle monitoring as part of the Ngeanges Eradication). Palau started a National GEF6 Project in late 2018 to address many of the key gaps addressed here (as well as on land), particularly as relates to invasive species and to species-based regulations and enforcement by the Division of Fish and Wildlife.

Most species work is still led by nonprofits, private entities, and Koror State. There is still demand for regulated and illegal species (e.g. dugong) and inadequate compliance and enforcement.

Correction and Update

The 2017 SOE stated that Palau had 4 potential marine pests (based on port surveys), which did not accurately describe the state of marine introduced species. Colin (2009) discussed around 20 marine introduced species. Campbell et al. (2016) detected a possible 40 marine introduced species. The two differed in their use of the word "pests." See Indicator 52.

Colin (2009) also discussed the difficulty in determining if a species is introduced, given hundreds of years of ship traffic and only recent advancements in taxonomy. One of the secondary benefits of CRRF's work on behalf of the U.S. National Cancer Intitute has been the identification of marine invertebrate and plant samples; this list of known species then is the foundation for a list of introduced species.

[8] Law allows export of cultured clams; wild clams have been exported; enforcement is needed. Clams are declining or very low in abundance (Indicator 20). *T. gigas* are particularly rare.

[9] Debusech, Omuu

[10] Basis for Grade: Subjective. Good = Laws, regulations, and enforcement are adequate to stop local decline; Fair = Either laws or enforcement must be improved to stop local decline; Poor = No additional restrictions and/or species is in decline despite laws.

MANGROVES

Photo by A. Gupta

Much of the data for this section was kindly provided by Palau Automated Land and Resource Information System (PALARIS). Additional information was found in published technical reports and gleaned from publicly available sources.

SDG 15.2.1

The Mangrove Management Plan (Metz 2000) and the proposed 2018 Sustainable Forest Management (SFM) Policy call for a "No Net Loss" Policy for forests. Determining whether Palau is meeting this policy directive is difficult: Mangroves naturally expand, but recent years have seen a decline in mangrove extent due to human use.

State of Mangroves

Mangroves in Palau are healthy and resilient. However, recent geospatial data on mangroves cannot be used to determine extent and trend, which is a major gap. Where known, over the long-term, mangroves have expanded; however the impact of that growth (e.g. on rarer habitats such as seagrass) remains unknown.

Baseline information on mangrove diversity and health is good (e.g. biodiversity in Metz 2000 and Mersai 2007; accretion rates in MacKenzie et al. 2016). However, there have been few follow-up studies to determine if baselines have changed. New work is ongoing to quantify carbon storage and trends. Palau's C Stocks are relatively high.

Pressures on Mangroves

Human use and clearing potentially impacts large areas of mangrove at a time. Pressures from climate change are low, and fungal growth remains an indicator to watch. There is no recent information on nearshore fishery status and use in mangroves.

Responses for Mangroves (and Gaps)

Setting aside Mangroves in Protected Areas remains Palau's primary response for mangroves. 33% of mangroves are managed in some way, although given the importance of mangroves to food and climate security, the target for management is 75%. The amount of mangrove in No-Take Protected Areas and the PAN is low. Mangrove MPAs appear to be performing well.

Research efforts into mangrove storage are ongoing, although these are largely led by nonprofits. However, there are no dedicated research efforts into the impacts of mangrove growth on rarer habitats such as seagrass. Palauan government management of mangroves (including a central source for information) remains a gap. Ongoing Land Use Planning efforts will continue to address mangroves. The SFM Policy has not yet been adopted, so there is not yet a policy imperative (or associated regulations) to adhere to "No Net Loss."

Issues in the 2017 SOE

The 2017 SOE cited a 2014 GIS value of 50 km^2, which may need to be revised given issues with the GIS shapefiles (Indicator 57).

New information shows that pressures from climate change (especially Sea Level Rise) are so far low. All other risks and gaps remain: unmitigated threats from human use and conversion, no central information authority, little mangrove monitoring.

Correction: New land classifications mean that area of mangrove in Protected Areas has been revised. See Indicator 62.

SDG 15.1.1

SOE Indicator 57. Mangrove Extent

PALARIS (2019) estimates nationwide mangrove extent (Figure I57a) to be steady at ~50 km^2. However, there are problems with the shapefiles in the GIS data, which do not align with soil layers (Kitalong, pers. comm.). For instance, 2016 and 2017 GIS data indicated a loss of over 2 km^2 of mangrove in Ngatpang, but this is not visible on the ground (Colin 2019), or visible using historical imagery on Google Earth, and may be an issue with classifications. Thus it is not possible to determine a nationwide trend.

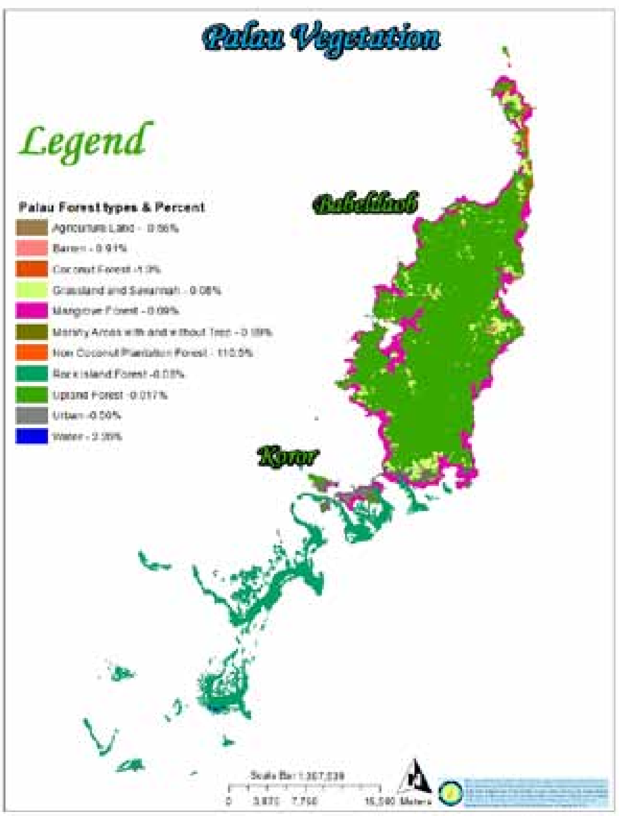
Mangrove extent clearly increased on Babeldaob between 1947 and 2005, but with lots of variation (Collins et al. 2015 using aerial imagery; Figure I57b).

Ground observations suggest that large areas of mangrove have been filled for development in Airai in recent years. Leases for conversion and/or development have been extended in Koror, Airai, and Aimeliik (Kitalong, pers. comm.).

Expansion of mangroves in Airai Bay was documented in the 2017 SOE. Seaward expansion of mangroves in Airai was influenced by sedimentation (Colin 2009), and at the expense of rarer seagrass beds. The rate of gain of mangrove in Airai was measured at 0.1 km^2/year (Neville 2014). Elsewhere, previously Neville (2014) estimated that mangroves were being lost at a rate of 0.04 km^2/year due to development.

The extent, impact, and cause of mangrove expansion or loss remains to be seen. Mangroves are dynamic systems that naturally grow vertically and horizontally (see below).

	State (km^2)[1]					Trend[2]
Year	*1983*	*1987*	*2006*	*2011*	*2014-2017*	*1983-2017*
Nationwide square area of mangrove	43.52	47.01	45.89	42.03	~50 (low confidence)	No clear trend



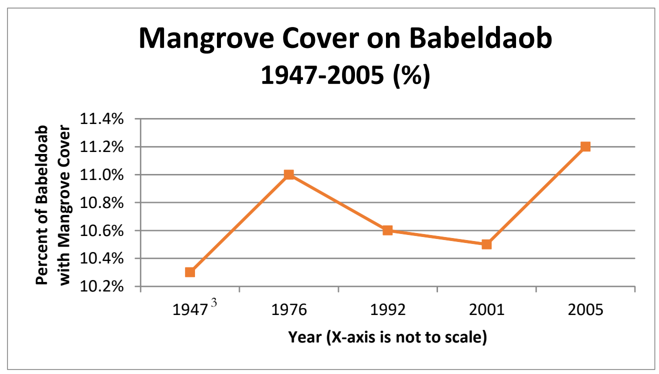


Figure I57b. Percent of total landcover on Babeldaob that is mangrove, over time. Graph created with data from CRRF (Collins et al. 2015). See "Landscape Change on Babeldaob Island, Palau" poster on https://coralreefpalau.org/education/posters/.

[1] PALARIS (2019). Unpublished. Analysis provided for this report.

[2] *Notes on Trend*: Given the importance of mangroves to fisheries, shoreline protection, and carbon storage, this report would treat the nationwide gain of mangroves as desirable and the nationwide loss as undesirable. However, this does not negate complex impacts, such as the gain of mangroves at the potential expense of seagrass beds.

[3] 1947 imagery was less accurate and extent of mangroves was difficult to distinguish manually (Collins et al. 2015).

Figure I57a (left). Mangroves (in pink) surround 80% of Babeldaob's coastline. Figure from PALARIS, based on Donnegan (2007).

Sedimentation, Accretion, and Accumulation rates

Mangroves can trap between 30 and 60% of sediment from land (Koshiba et al. 2013)

MacKenzie et al. (2016) established sedimentation rates, vertical accretion rates, and C accumulation rates for six disturbed (with roads) and undisturbed mangrove sites on Babeldaob. This data forms a baseline for future comparisons, and for planning given Climate Change (see Indicator 59).

- Average sedimentation rates did not differ between disturbed and undisturbed sites.
- Average vertical accretion rates were slightly lower in disturbed sites.
- Average sedimentation and vertical accretion rates were both nearly 2x times higher in fringe than interior sites.
- Percent C ranged from 9.8 to 34.6% and did not significantly differ between disturbed and undisturbed sites, or fringe and interior sites.
- Average belowground C accumulation rates did not significantly differ between disturbed and undisturbed sites, or fringe and interior sites.
- Percent C or C accumulation rates did not differ among individual sites.

SOE Indicator 58. Mangrove Carbon Stocks

Mangrove forests and the soil beneath them store significant amounts of carbon. Studies from Yap and Palau have shown that mangroves and their soil (to 1 m depth) store 2x as much carbon per hectare as tropical moist upland forests in Brazil and Mexico (Kauffman et al. 2011). Carbon in Palau's mangroves is in the moderate to high range when compared to oceanic mangroves in the Western Pacific (Donato et al. 2012).

Thus, when mangroves are cleared they release a disproportionate amount of carbon. Mangroves store 4-8 times the Carbon stored in savannas and 2-3 times that stored in upland forests (Table 1, Figure I58a). This is largely driven by belowground storage. Compared to upland soils, mangrove soils have much higher C concentrations. Mangroves account for 24% of Palau's total Carbon stock while only taking up 13% of total area (Donato et al. 2012).

Table 1. Mean Carbon Stocks, by forest type (Mg/ha)[1]

	Savanna	*Up. Forest*	*Mangrove*
Total aboveground C (mean)	5.1	216	131
Total belowground C (mean)	198	221	699
Total Carbon (mean)	203	437	830
Range of Ecosystem C	117-289	311-563	683-977
Total C, Palau	15.2 Tg Carbon		
Total CO_2 equivalent, Palau	55.8 Tg CO_2 equivalent		

[1] Donato et al. (2012)

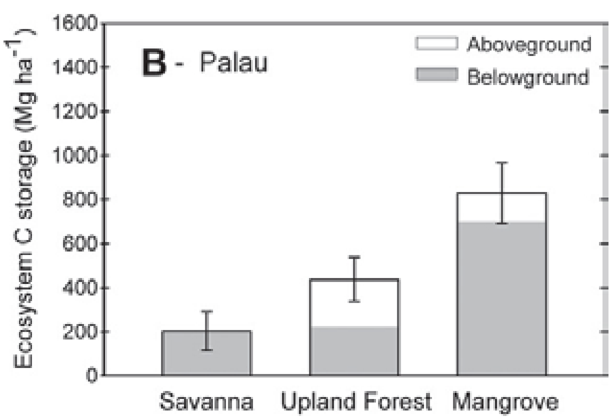


Figure I58a. C Storage by forest type. Figure modified from Figure 3 in Donato et al. (2012).

Kauffman et al. (2011) showed that Carbon storage is higher on the landward side, for above- and belowground C and for C stored in soil (Table 2, Figure I58b). The landward side, however, is threatened with development.

Mangrove C Stocks offer potentially valuable revenues for climate mitigation (Donato et al. 2012).

A 2010 study determined baseline C accumulation rates in multiple sites: the range of C accumulation at undisturbed sites was 69.8 to 369.7 gC/m²/year and 119.5 to 251.9 gC/m²/year at disturbed sites (MacKenzie et al. 2016).

Ongoing work (R. MacKenzie, 2019, personal communication) is determining trends. It appears that C Stock from mangrove trees increased between 2010 and 2015 in 5 out of 6 sites (both disturbed and undisturbed). This work is ongoing; plots and gear are in place to allow for follow-up monitoring.

Table 2. Mean Carbon Stocks, by mangrove forest zone (Mg/ha)[2]

	Seaward	*Interior*	*Landward*
Aboveground Tree C (mean)	81.4	98.0	133.7
Belowground Tree C (mean)	70	70	100
Soil C (mean)	314.9	428.4	818.4

[2] Kauffman et al. (2011)

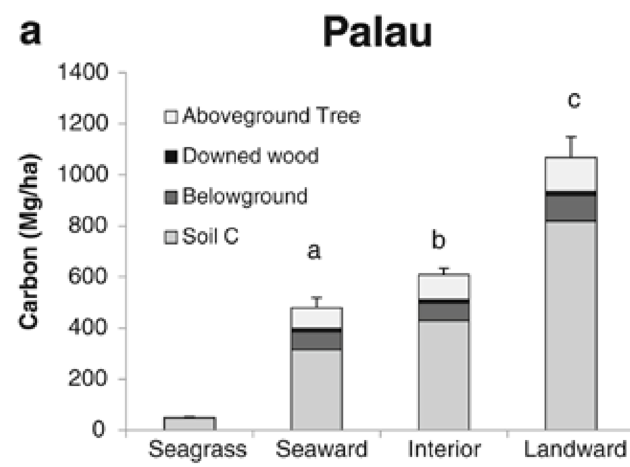


Figure I58a. Ecosystem C Stocks by mangrove zone. Figure modified from Figure 3 in Kauffman et al. (2011).

Orchid Communities (Upland Forest diversity)

This last-minute information, kindly provided by Ben Crain, should be in the Forest section but does not fit. There are orchids in mangroves, but this information is from Ngardok and upland forests.

Palau is rapidly gaining recognition for its diverse orchid communities, with close to 100 species that are believed to occur. Historical data on orchid communities in Palau exists, but much of the information associated with early collections was lost when herbarium specimens were destroyed in Europe. Currently, national level surveys are being conducted by collaborative researchers from the Belau National Museum, the Smithsonian Institution, and the US Forest Service as part of the Palau Orchid Conservation Initiative. Highly detailed surveys are also being conducted on the Forest Dynamics Monitoring plot in the Ngardok Nature Reserve, where many of Palau's orchids are known to occur.

Because orchids are highly sensitive to an array of environmental disturbances, they are valuable indicators of forest health. Initial broad level surveys indicate that orchids are widespread in Palau. Preliminary data from detailed surveys in the Nardok plot indicate a gradient in orchid communities associated with vegetation attributes; intact forests appear to support different orchid communities than more disturbed sites. Rarer natives and endemics appear to occur in intact forests, whereas more common species, and even invasive orchids tend to occur on more disturbed sites. Accordingly, long-term research on orchid communities in Palau will be invaluable for evaluating the effects of environmental disturbances as well as the effects of forest restoration efforts.

Overview of Pressures on Mangroves

Climate Change — Indicators 59

Clearing and Human Use — Indicator 60

Fungal Infection — Indicator 61

Climate Change Pressures:

SOE Indicator 59. Sea Level Rise, Increased Rainfall, and Typhoons

Sea Level Rise

Mangroves in Palau have low vulnerability to Sea Level Rise; depending on the rate of rise (Indicator 8). MacKenzie et al. (2016) measured vertical accretion rate at 11 sites (disturbed and undisturbed, fringe and interior). The accretion rate ranged from 1.8 to 9 mm/year. At a sea level rise of 2.7 mm/year, 4 of the 11 sites would not be growing vertically (vertical accretion) fast enough to keep up with the rise. At a 9 mm/year sea level rise, only 1 site would be able to keep up. Palau's mangroves are oceanic, have kept with past sea changes, and are adapted to a 2 m tidal range. Even at a 9 mm/year rise, mangroves would not be submerged for at least 175 years (MacKenzie et al. 2016).

Increased Rainfall

Increased rainfall (Indicator 11) is expected to have a positive influence on mangrove growth in the Pacific, due to increased sediment. Decreased ocean water salinity from increased rainfall may also increase mangrove production (Ward et al. 2016).

Typhoons

Typhoon Bopha had minimal impact on mangroves on Babeldaob, providing evidence for the protective factors of mangrove forests (Colin 2019). Kaufmann and Cole (2010) identified adaptations that may help mangroves recover post-storm.

SOE Indicator 60.

Clearing and Human Use

Human use and direct loss from development have the greatest pressure on mangroves, with areas of mangroves being leased and filled, without opportunities for public comment (Kitalong, pers. comm.). Mangroves fall under State government authority. The proposed 2018 Sustainable Forest Management Policy calls for a "No Net Loss" Policy for mangroves.

Mangrove damage has been observed from clearcutting and girdling. In Airai, trees had been girdled along a 500 meter-long stretch of channel, and mortality of girdled trees was 99% within 5 meters of the channel (Cannon et al. 2014 and documented by Colin (Figure I60)). In 2007, 100% of sites had signs of human damage (Mersai 2007).

Information on nearshore fishery harvest from mangroves is scarce. Stock of mangrove crabs appears to have diminished in recent years (Delos Santos, in Rengiil et al. 2017).

Figure I60. Aerial view of girdled mangroves (2010). Copyright Coral Reef Research Foundation (2019). Used with permission.

SOE Indicator 61. Fungal Infection

Mortality of trees from *Phellinus* spp. fungal infection was found in 3 out of 5 surveyed mangrove sites (60%) in 2014 (Cannon et al. 2014). In one site, 4% of all trees and 50% of all large *Xylocarpus* trees were infected. In another site, 5% of trees were dying, many with rotten limbs.

Many mangrove species are vulnerable to colonization by fungal species even after minor damages. Outreach and education can allow for sustainable use of mangrove trees, while limited collateral damage to and fungal invasion of nearby trees.

PNC 14.5.1

SOE Indicator 62.

Mangrove Protected Area (PA)

PALARIS obtained a new Mangrove data layer in 2017 with improved land cover classifications, so values have been revised significantly from the 2017 SOE.

In 2019 there were 15 PAs with mangrove, in 9 of the 13 States with mangroves. They captured 33% of Palau's total mangroves. Ngeremeduu Bay (54%), the Rock Island Southern Lagoon (10%), and the Ngaraard Mangrove Conservation Area (9%) make up 72% of the total protected mangrove. 9 of these areas in 5 States are No-Take; 9 sites in 7 States are in PAN.

Following the methods in Indicator 9, MPAs with mangroves appear to be performing well, although the sample only includes Airai and Ngaraard. In these two states, 77-91% of all Socioeconomic survey respondents said their protected areas increased targets or agreed with statements (e.g., "Availability of food" or "Provides livelihood benefits"). See Indicator 9.

	State[1]	Grade[2]	
Total managed	16.5 km^2 (33% of total)	Fair	Good
Total No-Take	3.9 km^2 (8% of total)	Poor	
Total in PAN	3.8 km^2 (7.6% of total)	Poor	
77-83% people said PA increases targets		Good	
80-91% Agreed with PA Value statement		Good	

[1] Mangrove totals from PALARIS; Koror RISL mangrove from 2012 World Heritage Dossier.

[2] *Basis for Grade:* Progress toward desired target. Good >75%; Fair = 40-75%; Poor<40% of way to target. Management Plan (Metz 2000) target for managed area is 75%. Palau is 44% of the way to the Management Plan target. No-Take and PAN areas are only 25-27% of way to Micronesia Challenge's 30% Effective Conservation target. Also see Indicator 9.

Much of the data for this section was kindly provided by Palau Automated Land and Resource Information System (PALARIS) and the Coral Reef Research Foundation (CRRF). Additional information was found in published technical reports and gleaned from publicly available sources.

SDG 15.2.1

The proposed 2018 Sustainable Forest Management (SFM) Policy calls for a "No Net Loss" Policy for forests. Adopting and implementing the SFM Policy will help Palau achieve Sustainable Development Goal 15 (Life on Land), specifically Indicator 15.2.1 (Area under sustainable forest management).

State of Forests

With the exception of burned areas, forests are in Good condition, with high diversity. Extent of forest is expanding, although this is secondary vegetation. Recent landcover change is not known, and loss of primary forest is also unknown.

There is a lack of public data on freshwater quality and quantity, and there is no regularly monitoring of water or freshwater biodiversity. However, trends indicate that the extent of damaged and degraded lands and forests, and the amount of damaged trees, is increasing. The number of endangered species on land has increased steadily.

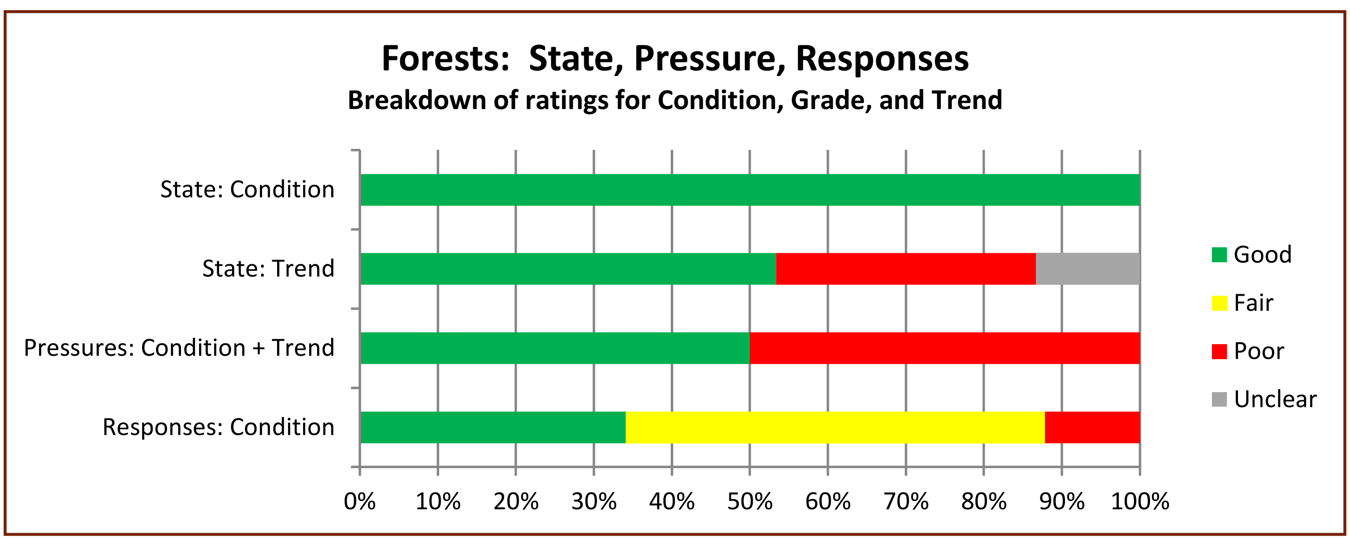
Pressures on Forests

Fire and Climate Change pose significant threats to forests and freshwater. While still posing a threat, pressures from Invasive Alien Speces seem to be better controlled and Palau has implemented measures to reduce their threat. While unsustainable human use is known to be a pressure, there is little information available to quantify or track its extent.

Responses for Forests (and Gaps)

Extent of Terrestrial Protected Area has increased but is still too low. Performance of Terrestrial Protected Areas is Fair to Good for socioeconomic indicators, but unknown for biophysical indicators.

Information on endemism, distribution, and status of terrestrial plants has increased significantly. However, many plant species are now known to be threatened or endangered, and few are managed.



SDG 15.1.1

SOE Indicator 63. Forest extent and change

Data suggest that forest cover is expanding, although data for recent years is still in development. PALARIS has data layers from 1987 (Cole et al. 1987) and 2003 (Donnegan 2007), but they used different methods and criteria. Additional layers that quantify land cover change are still in development; for instance PALARIS completed agricultural mapping in 2015. The 2015 estimate of nationwide forest cover took into account expansion of forest, mangrove, and considered areas of development. However, confidence in the recent nationwide trend is low. Nationwide forest cover includes the nearly 100% forested Rock Islands.

Forest expanded on Babeldaob between 1947 and 2005 (CRRF: Collins et al. 2015; Figure I63a). This data was derived by comparing aerial photos and satellite images from different time periods; confidence in the Babeldaob trend is high. Forest decreased in Koror, Peleliu, and Angaur between 1988 and 2005 (Donnegan et al. 2007; Figure I63b). Non-forest vegetation decreased on Babeldaob but increased on Koror, Peleliu, and Angaur between 1988 and 2005. Urban area increased in all locations in that same timeframe.

Interestingly, there may be an answer to the question "Are savannas native/natural habitats in Palau?" Costion et al. (2011) discovered evidence that 55% of Palau's savannas are anthropogenic in origin, and by inference concluded that "Palau was essentially a forested landscape with probably very few pockets of open terrain." 26% of Palau's volcanic terrain on Babeldaob was disturbed (historically), raising interesting questions about the biodiversity value of ancient and historic sites.

	State (km^2)						Trend[5]	Condition[6]
	1947[1]	*1976/87*	*1992[1]*	*2001[1]*	*2003/5*	*2015[4]*		
Nationwide Forest cover *(low confidence)*		80% [2,9]			82%[3,9]	87%	Increased	Good
Babeldaob Forest Cover[1] *(high confidence)*	61.7%	68.2%	68%	70.5%	71.7%		Increased	Good

	State (km^2)			Trend[5]
By Island:	*1988*	*2005*	*% Change*	
Babeldaob[7]	~283	~295	+4%	Increased
Koror[7]	~6.1	~5.3	-13%	Decreased
Peleliu[7]	~15.4	~14.2	-8%	Decreased
Angaur[7]	~7.3	~6.5	-11%	Decreased
Nationwide:	*1976*	*2005*	*% Change*	
Limestone[8]	38.9	70.1	+80%	Increased
Volcanic[8]	291.2	296.9	+2%	Increased
Total forest[8]	330.1	367.0	11%[9]	Increased
Non-forest vegetation[8]	73.9	62.0	-16%	No basis

[1] CRRF (Collins et al. 2015). 1947 imagery was less accurate.
[2] Cole et al. (1987) included agroforest and secondary forest vegetation; used aerial photographs to map areas with 30% or greater canopy.
[3] Donnegan et al. (2007) included agroforest and secondary forest vegetation; used satellite imagery to map areas with 10% or greater canopy.
[4] SDG Report (Pacific Islands Secretariat Forum 2018). Low confidence due to low resolution.
[5] *Notes on Trend*: Increasing forest cover is deemed "Healthy/Desirable" for the following reasons: From a biodiversity perspective, historical data indicates that Palau was once nearly 100% forested; forest health indicators show that forest expansion is driven by native species and not introduced species, and thus healthy; and forests provide essential ecosystem services included maintenance of water quality and quantity.
[6] *Basis for Grade:* 30% Forest Loss appears to be a threshold for biodiversity maintenance (Estavillo et al. 2013); in both 2005 (high confidence) and 2015 (low confidence), forest cover is over 70%.
[7] Estimated from Figure 6 in Donnegan et al. (2007). Acres converted to km^2.
[8] From Table 2 in Donnegan et al. (2007). Converted to km^2.
[9] Methods and criteria changed between the two time periods, and discrepancies between the data remain.

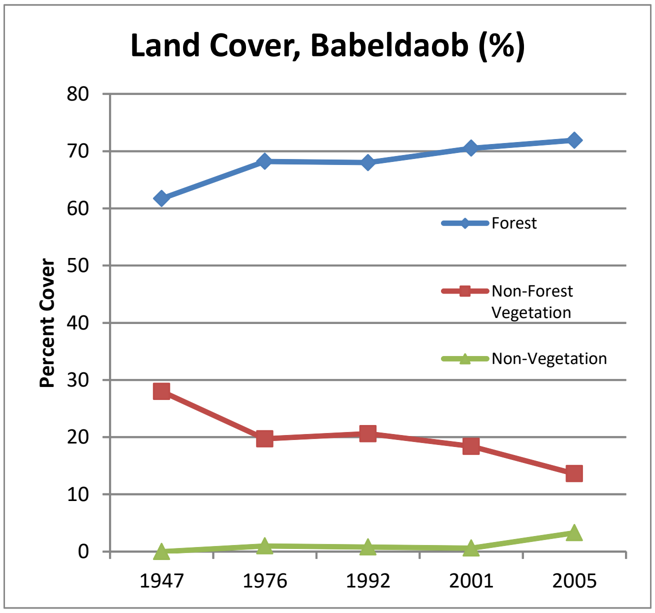


Figure I63a. Percent of total landcover on Babeldaob that is forest, non-forest vegetation, and vegetation, over time. Graph created with data from Collins et al. (2015). See "Landscape Change on Babeldaob Island, Palau" on https://coralreefpalau.org/education/posters/.

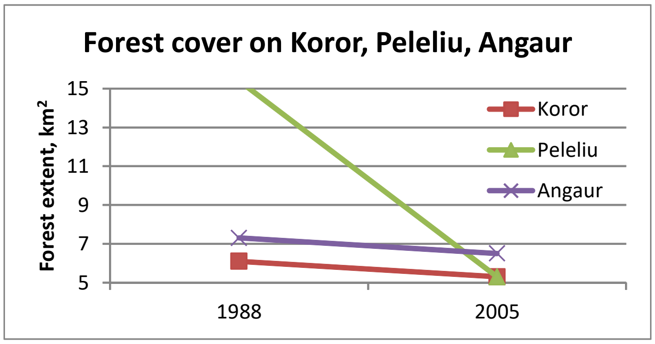


Figure I63b. Total forest (km^2) on Koror, Peleliu, and Angaur in 1988 and 2005. Estimated from Figure 4 in Donnegan et al. (2007).

SOE Indicator 64. Forest diversity

There is good baseline information on forest diversity from decadal Forest Inventory Analysis (FIA) surveys with the USDA Forest Service, regular PAN monitoring, and via the establishment of a detailed, high resolution Forest Dynamics Monitoring plot in the Ngardok Nature Reserve.

In 2014, the one hectare Ngardok Nature Reserve plot contained 62 species of native woody plants, 29 of which are endemic to Micronesia and 21 endemic to Palau (Forest Service 2014). No single species dominated (Figure I64). Species diversity in the forest was nearly 3x higher than in the savanna. The Palau plot has more than 3x the tree species than a larger plot in Hawaii, and a similar density of tree stems per hectare as other tropical forests. Forest structure (size of trees) was also diverse in different sites. *See also information on Orchids on p. 56.*

The FIA Surveys provide nationwide information on tree densities and diversity. Palau's forests are relatively dense and have high species diversity (Forest Service 2014). In the 2003 FIA Survey (Donnegan et al. 2007), a total of 128 tree species and 132 understory species were measured on FIA plots. In the 2014 FIA Survey (MC 2018), 126 tree species were recorded; 32 tree species made up 75% of forest structure, with no one single species dominating. Diversity of tree size (stem and height) was also present, indicating diverse forest structure.

	State[1]		Trend[2]	Condition[3]
	2003	*2004*		
Species of trees in FIA	128	126	Stable	Good

[1] 2003 FIA (Donnegan et al. 2007); 2014 FIA Summary from MC (2018).
[2] *Notes on Trend*: Palau is highly diverse. Maintenance of that diversity, much of which is endemic, is in national environmental policies (e.g. in the 2015-2025 NBSAP).
[3] *Basis for Grade:* Subjective. Highly diverse forests appear to be Palau's natural state, and tend to be more resilient to climate change.

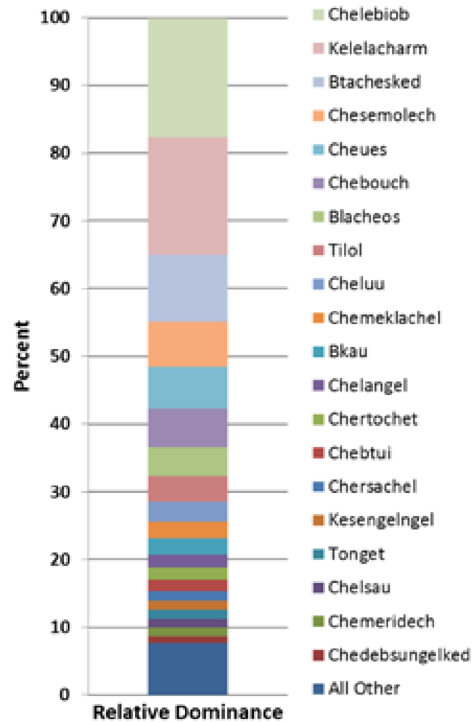


Figure I64. 20 most dominant tree species in the Ngardok Nature Reserve Plot. Figure from Forest Service (2014).

SOE Indicator 65. Degraded and Disturbed Lands

SDG 15.3.1

Barren areas are known to erode and negatively impact freshwater and marine resources.

In 2014, total forest land that had been disturbed added up to approximately 30% of Palau's total land. This included all disturbances: fire, animal damage, wind, tree disease, invasive species, and vegetation suppression (e.g. cutting) (calculated from FIA 2014-Forest Inventory Survey Data).

See also Indicator 68 on Fire.

	State (km² & % total land)			Trend
	1976	*2005*	*2014*	
Barren area	1.4 km² 0.33%[1]	4.5 km² 1.0%[1]		Increased
Disturbed forest land			125 km² 30%[2]	No basis
Degraded land		*2000-2015* 108 km²; 26.2%[3]		No basis

[1] Donnegan et al. (2007)
[2] Analyzed using 2014 FIA Data. Includes all possible disturbances, but does not consider severity of damage.
[3] UNCCD (2018 - Palau Country Report). Low confidence due to low resolution of data. UNCCD indicators on land cover, land productivity dynamics and soil organic carbon stock used to compute land that is degraded.

SOE Indicator 66. Tree Damage

The most prevalent damage to trees in 2014 was from disease (in 2003 the prevalent damage was from other vegetation[1]). In 2014 there was little damage specific to weather (in the FIA plots).[3] Damage types included: fungal infections/decay, invasive vines, loss of apical dominance/dead terminal, disease, weather, insects, fire, and human-caused damage.

	State (% trees)		Trend
	2003[2]	*2014*[3]	
Percent of individual trees with any damage	13%	20.4 to 29.2%	Increased
Dead trees	<5%	1%	Stable or Decreased

[1] Julian Dendy, pers. comm. [2] Donnegan et al. (2007)
[3] From 2014 FIA Data, by Julian Dendy (95% Confidence Interval)

SOE Indicator 67. Forest Carbon

See Indicator 58. Upland forests in Palau hold 69% of Carbon Stocks, or 10.6 Mt. Savannas hold 7% of C Stocks, or 1.04 Mt (Donato et al. 2012).

Upland Forest:	*Mg/ha*[1]
Trees	204
Understory	4.9
Downed wood	7.3
Roots	37
Soil	185
Total	437

[1] Donato et al. (2012)

Overview of Pressures on Forests

Fire	Climate Change	Invasive Species	Fungal Infection	Unsustainable Human Use
Indicator 68	Indicators 69	Indicator 70	Indicator 71	Indicator 72

SOE Indicator 68. Fire

This information was kindly provided by Julian Dendy.

A partnership between CRRF, Palau Forestry Division, and the USDA Forest Service mapped the extent and impact of fire on Babeldaob over 7 years from 2012 to 2018 (Figure I68a).

There were on average 173 fires per year, which burned an average 3,000,000 m^2/year (3 km^2); or ~1% of Babeldaob.

There were an average of 122 fires per state, which burned an average of 5.7% of each Babeldaob state's total area (including mangroves). Airai had the most fires, Ngaremlengui had the most area burned, and Ngarchelong had the greatest percentage of total area burned.

43% of fires burned some forest edge, and 28% indicated the presence of invasive species. There was an average of 15 fires/year inside Protected Areas.

6% of fires were within 10 m of streams, 1% were within 10 m of coastline, and 6% were within 10 m of mangroves; these fires had likely erosion and sedimentation impacts.

Over the seven years of the study ~23% of the total non-forest vegetation area (including non-vegetated area) and ~1.3% of the total forest area of Babeldaob Island was burned.

Dendy et al. (2019) observed structures destroyed by fire, powerlines that were nearly damaged, many minor landslides, obvious evidence of erosion, and fires that burned into wetlands or to the very edge of steep coastline. They commonly found damage and destruction to agricultural and agroforestry resources (e.g. coconut and mahogany groves or taro patches).

The top three reasons for burning were hunting, arson, and farming (Figure I68b). Based on the spatial statistics, Dendy et al. (2019) concluded that at least 15% of the total burned area, which was more than 500 m from roads, is due to hunting; as hunters are usually the only people who access those areas. Since burning in the interior areas of Babeldaob seems to be a reliable indicator of hunting activity, they surmised that hunting has been commonly occurring inside Protected Areas.

Areas burned repeatedly from 2012-2016, ~7% of total non-forest vegetation on Babeldaob, are likely to be problematic in terms of increased vulnerability to invasion by non-native plant species, erosion, and degradation of soils, which can lead to barren areas that are constant sources of sediment.

More fires occurred in January, February and March than in other months. Longer stretches of hotter and drier conditions, like during El Niño events, probably lead to more and larger fires. 2015 was likely an El Niño year, and in 2015 Babeldaob experienced the most total area burned per year study.

Between 2007-2009, 68 fires reported to the Bureau of Public Safety burned a total of 0.07 km^2 (Kitalong 2010-SWARS), far less than the average of 1% of total island area burned annually from 2012-2018, which indicates that fire is more pervasive on Babeldaob than previously thought, and that most fires go unreported. Rates of forest loss and recovery over time estimated from remote sensing comparisons indicate that the average rate of forest loss from fires over the past 7 years is potentially less than the overall average annual forest loss from 1976 to 1992, so the average level of burning since 2012 has likely not increased substantially and may have decreased somewhat compared to that time period. The FIA 95% Confidence Interval estimate for Percent of Forest Area Disturbed from Fire on Babeldaob (2004-2014) was between 1.5% and 16%.

Fire suppression and/or prevention is essential for forest restoration efforts to be effective (Dendy et al. 2015). The PAN initiated fire breaks (shaded fuel breaks) in 2018 in strategic locations within protected areas (Lake Ngardok Nature Reserve, Ngardmau) based on recent fire history and distance to roads.

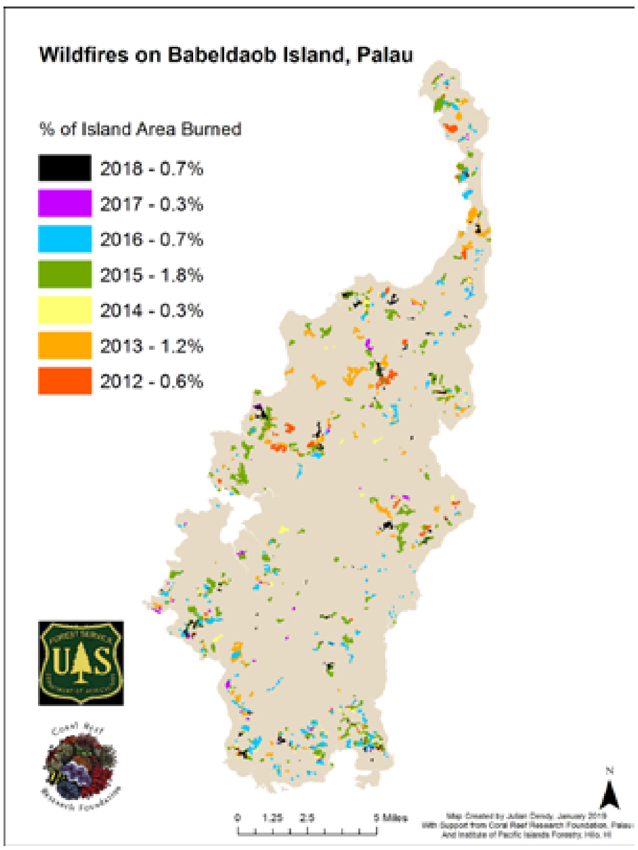


Figure I68a. Map of fire occurrence on Babeldaob Island, Palau from 2012 to 2018. Figure from Dendy et al. (2019).

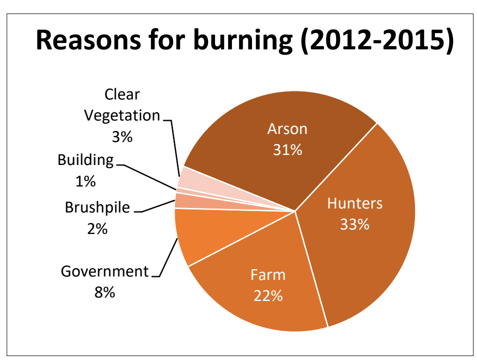


Figure I68b. Reasons for burning, 2012-2015. Figure created from data in Dendy et al. (2019).

Climate Change Pressures:

SOE Indicator 69. Rainfall Variability, Typhoons, and Temperature

Palau's forests are highly vulnerable to Climate Change.

Rainfall Variability

Forests in Palau are predicted to experience wetter wet seasons and drier dry seasons, but with overall increases in mean annual rainfall (Indicator 11). Higher rainfall may accelerate erosion (Neville 2014), including loss of topsoil, organic material, and nutrients. Tree species not particularly adapted to drought will be stressed throughout the dry season, and an increased dry season may increase the risk of fire (Indicator 68) (Neville 2014). Prolonged rainfall is associated with loss of flowers and less fruiting (ADB 2011).

Typhoons and Storms

Typhoons in 2012 and 2013 were responsible for uprooting trees and vegetation, causing landslides, and washing away topsoil; Angaur (Bopha) and Kayangel (Haiyan) had drastic loss of trees (Figure I69a). With 88% of the island at a slope of 12% or greater, the majority of Babeldaob is at medium to high risk of slope failure following intense rainfall events (Figure I69b; Kitalong 2010). Palau's steep riparian areas are highly vulnerable to slope failure and loss of topsoil and/or vegetation.

Temperature Variability

Increasing temperature is associated with increased incidence of some diseases (Bourke and Harwood 2009) particularly those influenced by rainfall and humidity. There may also be increased incidence of pests (ADB 2011). Changes in temperature may change seasonal patterns of fruiting trees and plants (FAO 2014).

Figure I60. Loss of forest in Angaur after Typhoon Haiyan. Copyright Coral Reef Research Foundation (2019). Used with permission.

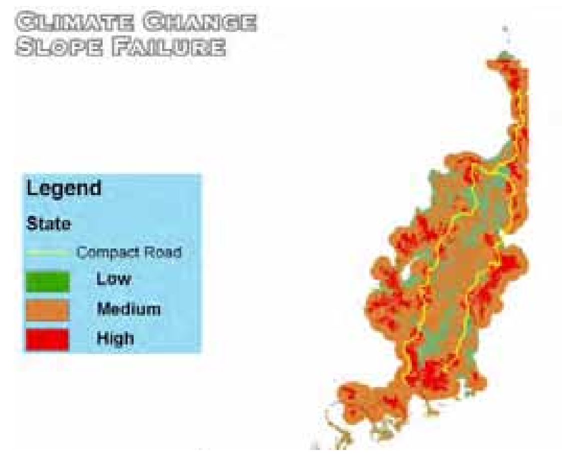


Figure I69b. Most of Babeldaob is at medium to high risk of slope failure following intense rainfall. Figure from Kitalong (2010-SWARS).

SOE Indicator 70. Alien Invasive Species

Invasive Alien Species (IAS) pose a significant threat to Palau's forests, but this threat appears to have remained stable in recent years. Palau's response to IAS has improved significantly. Palau completed its National Invasive Species and Biosecurity Strategic Action Plan (NISSAP) 2018-2022. A National GEF6-funded project is building national capacity to implement IAS prevention, control, and mitigation.

Exotic, fire-adapted grasses, such as Cogon Grass (*Imperata cylindrica*) are a threat on Babeldaob. These grasses quickly move into the understory, increase fuel loads (Indicator 68), quickly regenerate after fire, and suppress native vegetation (Neville 2014). Most of the existing populations are at or near the airport (Forest Service 2017) and are the subject of ongoing eradication efforts.

44% of tree damages in the 2014 Forest Inventory were associated with invasive vines in the crowns (*Mikania micrantha* and *Merremia peltata* (Kebeas)) (Neville 2014). A 2017-2018 Kebeas Control Project supported the removal of the vine in several states throughout Palau. Over 6 days in 2017, volunteers and employees removed at least 24.7 ha (0.24 km^2) of Kebeas. This consisted of 8.9 ha in Ngchesar, 12 ha in Melekeok, and 3.8 ha in Airai. A section in Ngaraard was also cleared. The level of effort (for Ngchesar, Melekeok, and Airai) was 73 person-days (~0.33 ha/person/day). In 2018 another 0.16 ha was cleared in Ngkeklau (Ngaraard) and 13.5 ha in Ngardmau. Funding from the US DOI will support removal of Kebeas from protected areas in Babeldaob and Koror (PCS 2019).

Asian cycad scale was detected in 2008 on ornamental cycads in Koror, where *Cycas micronesica* (Endangered, see Indicator 76) also occurs. A predator was released after the infestation was discovered and appears to have reduced scale populations enough that ornamental cycads showed no signs of infestation or damage in 2013. Palau's most important population of *C. micronesica* is on the Rock Islands to the south; the scale had not dispersed there as of 2013 (Neville 2014). Import of ornamental cycads is prohibited.

After Coconut rhinoceros beetle (CRB) was introduced to Palau in 1942, Palau lost almost 50% of its coconut trees (Neville 2014). Recent outbreaks of CRB in Palau have involved the CRB-G biotype, which is genetically distinct from other populations in the Pacific, resistant to currently available biocontrols, highly invasive, and has a very low response to pheromone traps (Forest Service 2016). There are several ongoing research efforts into CRB Biotypes and their biological controls (e.g. Oryctes virus) (Neville 2014).

SOE Indicator 71. Fungal Infection

Phellinus noxius is an aggressive, deadly root rotting pathogen. Several other species of the *Phellinus* genus also occur. This fungus spreads from tree to tree via root systems and kills tissue of the host tree. Several species important to agroforestry, including breadfruit, betel nut, mango, and ka, are hosts for *P. noxius*. The US Forest Service and *P. noxius* experts from Japan conducted surveys for this fungus in the forests of Palau and determined the fungus is widespread (Neville 2014).

Palau has made good progress in identifying and mapping the distribution of many *Phellinus noxius* infection foci (Forest Service 2016).

SOE Indicator 72.

Unsustainable Human Use

Poaching and Deforestation are regularly identified as threats to Palau's forests and terrestrial resources (e.g. in the 2018 Sustainable Forest Management Policy, which was based on consultations), but data to quantify the extent of this threat is minimal.

Indicator 63 shows that forests expanded on Babeldaob between 1992 and 2005; however at the same time the area of non-vegetation increased from less than 1% in 1992-2001 to over 3% in 2005 (Indicator 63). Identifying the rate and location of urbanization is an urgent need (Figure I72).

Indicator 68 suggested that several uses of Babeldaob (e.g. hunting, clearing) are done using unsustainable methods (such as fire) or are in protected areas.

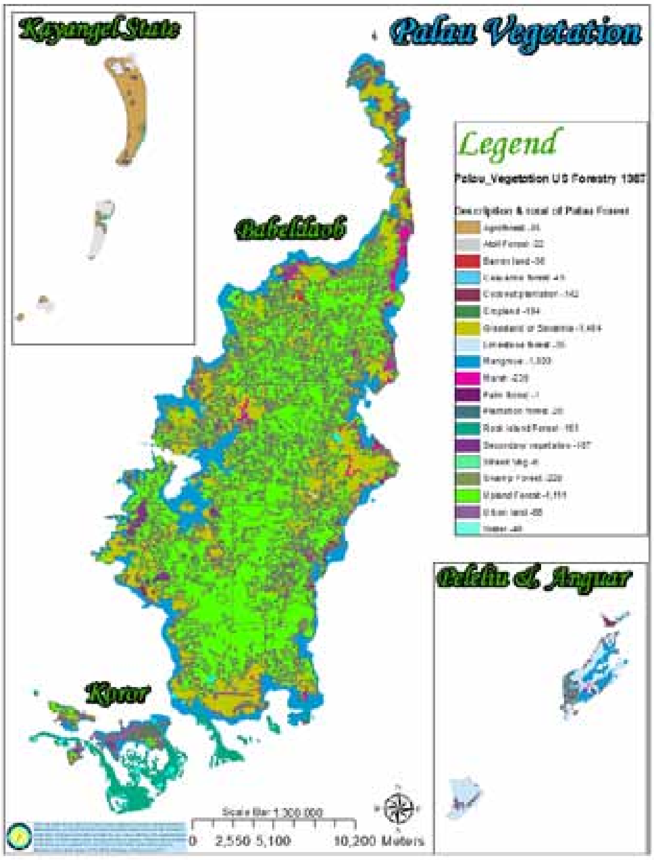


Figure I72. Map of vegetation and land over in Palau. Figure from Cole et al. (1987). There is minimal data available to quantify the extent and type of human use, much available data is 30+ years old.

SDG 15.4.1

SOE Indicator 73. Coverage of Protected Areas relative to terrestrial area

Extent of Terrestrial Protected Area has increased for almost all indicators. Total Managed area increased from 20 to 25% of total land area, and Total land protected on Babeldaob increased from 10 to 12%. Amount of protected terrestrial area is still far below conservation thresholds and national and regional goals. See also Indicator 37.

More Terrestrial Protected Areas are needed, and no indicators were graded as Good. Key areas for biodiversity (such as Important Bird Areas) are not adequately protected.

The number of types of habitats represented in protected areas and the PAN has increased; however, there are still habitats that are underrepresented: Beach strand, Raised coralline atoll, Swamp forest, and Bird aggregation sites.

	State[3]				Grade	
Type	*km²*	*Total land*	*%*	*# sites*	*2019[4]*	*Compared to:*
Total Terrestrial Managed Area[1]	102.6 km²	410 km²	25%	20	Fair (54%)[4]	ERA Goal, 46%
Total Terrestrial Managed Area, Babeldaob	42.7 km²	362 km²	12%	13	Poor (26%)	
Total No-Take[2] Terrestrial Area	41.59 km²	410 km²	10%	14	Fair (59%)	Aichi #11, 17%
No-Take Terrestrial Area, Babeldaob	27.24 km²	362 km²	8%	9	Fair (47%)	
Total Terrestrial area in PAN	40.68 km²	410 km²	10%	16	Fair (50%)	Micronesia Challenge, 20%
Terrestrial area in PAN, Babeldaob	33.76 km²	362 km²	9%	12	Fair (45%)	
Important Bird Areas (IBA), managed	85.34 km²	243 km²	35%	10	Fair (43%)[5]	ERA Goal, 80%

[1] Does not include mangroves. Includes all managed or protected areas (all IUCN categories, including VI for sustainable use).
[2] Designated as No-Take or as IUCN Categories Ia, Ib, II, III, or IV.
[3] Protected area coverage provided by PALARIS, February 2019, and adjusted to remove redundancy (so areas in Rock Islands are not counted twice).
[4] *Basis for Grade:* Comparing current progress to target or goal. Good = >75%. Fair = 40-75%. Poor =<40%. Meaning, having 25% managed area is 54% of the way to the ERA Goal of protecting 46% of terrestrial land.
[5] The Percent of IBA protected was revised and decreased. A new site was identified as an IBA (Northern Peleliu Lkes (sandflats)), which is not protected. Total IBA area from BirdLife (2019).

SDG 15.1.2

SOE Indicator 74.

Protected Freshwater Sites

Palau's two freshwater lakes are protected and in PAN. Of Palau's 621 km of freshwater streams and rivers, 16% of their length pass through a protected or managed area. Only 6% of freshwater streams pass through a PAN site. 7% of fires were near streams (Indicator 68). Perceived effectiveness for water variables is Good (Indicator 75).

	State[1]		**Grade[2]**
Type		*%*	*2019*
Freshwater lakes protected	2 lakes	100%	Good
Freshwater streams protected	99 km	16%	Good (80%)
Freshwater streams in PAN	36 km	6%	Poor (24%)

[1] Data from PALARIS (2019). [2] Compared to Micronesia Challenge (20% of total). *Basis for Grade:* Comparing current progress to target or goal. Good = >75%. Fair = 40-75%. Poor =<40%.

SDG 15.4.1

SOE Indicator 75.

Terrestrial Protected Area Management Effectiveness: Perceived Socioeconomic and Ecological impacts

How community members perceive Terrestrial Protected Areas varies wildly. PICRC conducts socioeconomic monitoring in sites with MPAs; many of these States also have Terrestrial Protected Areas and thus are assessed for their benefits as well. The survey asks about perceived benefits. Five surveys completed in 2016 to 2019 (for States with Terrestrial Protected Areas) were averaged below. The majority of respondents did not perceive any change due to the Terrestrial Protected Areas; for all indicators there was a larger percentage of respondents who perceived increased (healthy/desirable) impacts.

These 5 reports were used in Indicator 39 as well; that indicator also included an additional 4 studies for States with Marine Protected Areas only (no Terrestrial). Level of Agreement is consistent whether or not Terrestrial areas are separated: Protected areas are perceived as providing livelihood, economic, and environmental benefits; but few perceive cultural/spiritual or equitable benefits.

A Terrestrial Monitoring Protocol for PAN Sites is in development. Baseline data has been collected and has been reported in other indicators, where appropriate; some data is not yet tied to specific Protected Areas (PAs). According to the 2015 PAN Status Report 36% of Terrestrial PAs had average scores of "Good" or "Adequate."

Ecological scores have likely improved (or will in the near future) due to invasive alien species eradication and control.

State (Average and Range, N=5)[1]				**Grade[6]**
Perceived Impact on:[2]	*Increased[3]*	*No change*	*Decreased[3]*	
Overall quality of the terrestrial environment	30	51	7	Good
Spiritual and cultural amenity	13	55	8	Good
Abundance of fruit bats	19	48	13	Fair
Size of fruit bats	14	53	12	Fair
Abundance of medicinal plants	20	48	10	Fair
Availability of farm food (crops)	20	54	10	Fair
Abundance of building materials	26	48	10	Fair
Size of building materials	22	53	9	Good
Quality of public freshwater	20	42	6	Good
Quantity of public freshwater	19	44	6	Good
Level of Agreement with:	*Strong[5]*	*Moderate/Little[5]*	*None*	
Protected Area provides livelihood benefits	48	41	7	Good
Protected Area provides economic benefits	57	31	6	Good
Protected Area provides cultural/spiritual benefits	44	32	11	Fair
Protected Area provides environmental benefits	60	32	4	Good
Protected Area provides equal benefits	46	29	20	Fair

[1] Socioeconomic surveys from 2016 to 2018 for:
1. Marino and Jonathan (2018-Melekeok)
2. Koshiba et al. (2016-Kayangel)
3. Koshiba et al. (2016-Ngchesar)
4. Koshiba et al. (2016-Ngiwal)
5. Koshiba et al. (2016-Ngaraard)

[2] In two separate parts of the Socioeconomic survey, interviewees were asked about the impact of the MPA on Livelihood factors and their level of Agreement with Attitudinal Statements; not all are presented here.

[3] Values are condensed. "Increased" includes sum of respondents who answered "Greatly increased" and "Somewhat increased." "Decreased" sums for "Greatly" and "Somewhat" Decreased.

[4] This includes the range across two different livelihood factors which were presented separately (e.g. Abundance of fish and Abundance of invertebrates).

[5] Values are condensed. "Strong" includes sum of respondents who answered "Very Strongly Agree" and "Strongly Agree." "Moderate/Little" sums for "Moderately Agree" and "Agree a Little". "None" is the percent of respondents who answered "Do Not Agree."

[6] *Basis for Grade:* Subjective. *Perceptions:* Those with 10% or more who perceived a decline were graded "Fair." *Agreement:* Those graded as Good have total agreement above 80% and disagreement below 10%. Those graded as Fair have disagreement above 10%.

SOE Indicator 76. Endangered Terrestrial Species in Palau

Endangered birds are well understood, and there is new knowledge about plants. Plants here use the Endangered listing from the previous Palau Endangered Species Act (ESA); Birds list the proposed 2018 ESA List. The number of globally endangered Red Listed species in Palau has steadily increased.

Both of Palau's two native terrestrial mammals (both bats), are now on the Red List (100%). Of 46 known reptiles and amphibians (Crombie and Pregill 1999), one is on the Red List (2%), although most have not been assessed. Palau's one known endemic amphibian (the Palau wrinkled ground frog; SPREP 2016) is not listed as endangered. 40 native freshwater fish are known from Palau (Bright and June 1981), but none have been assessed for status and thus none are on the Red List. The number of Native Resident birds on the Red List has been steadily increasing, up from 4 in 2005 to 6 in 2019; with 2 now listed as Endangered. Thus, 12% of native birds are now on the Red List. The 2016 Country Data Dossier for Aichi Target 12 (SPREP 2016) estimated that 8% of plants in Palau are threatened. The number of endangered fish and invertebrates relative to the total number present in Palau is likely low, but most have not been assessed, either for local population or for global status. See also Indicator 56 (marine species, p. 52).

		State				**Grade**[3]
Class	*Common name*	*Red List*[1] (IUCN)	*Global Trend*[1] (IUCN)	*ESA*[2] (Palau)	*Palau laws/ regulations*	*Palau's responses*
Mammal	Pacific sheath tailed Bat	EN	Decreasing		No restrictions	Poor (None)
	Palau Fruit Bat (CITES I; See [3], p. 52)	NT	Stable	TH	Export ban	Fair
Reptiles	Pandanus Skink	NT	Stable		No restrictions	Poor (None)
Birds - Native Resident (Year-round, Breeding)[5]	Micronesian Megapode (Bekai)	EN	Decreasing	EN	Protected Land Life Act (PLL)	Fair (Indicator 81)
	Palau Ground Dove	EN	Decreasing	VU		Fair (Indicator 82)
	Nicobar Pigeon	NT	Decreasing	VU		Good - Local increase
	Micronesian Imperial Pigeon	NT	Decreasing	EN / VU		Fair (Indicator 78)
	Giant White Eye	NT	Decreasing	NT		Good
	Palau Nightjar	NT	Stable			Good
	Palau Kingfisher (Cherosech)	NT	Stable	NT		Good
	White-breasted Woodswallow			CR		Fair
	Common Moorhen, Greater Crested Tern			VU		Good
	Australasian Swamphen (Wek)			VU	PLL Exempt	Poor (None)
	Great Frigatebird, Red-footed Booby, Brown booby, Sooty Tern			NT	Protected Land Life Act	Fair - Mortality in SW
Birds - Migrants (Regular visitors, wintering)[5]	Japanese Night Heron	EN	Decreasing			Fair - Essential and primary migratory site in Palau not protected (Peleliu Lkes IBA) Few Shorebird sites protected or managed
	Far Eastern Curlew (Delerrok); Great Knot	EN	Decreasing	CR		
	Providence Petrel , Matsudaira's Storm Petrel, Common Pochard	VU	Varies			
	Bar-tailed Godwit	NT	Decreasing	CR		
	Black-tailed Godwit, Eurasian Curlew, Red Knot, Streaked Shearwater	NT	Decreasing			
	Curlew Sandpiper	NT	Decreasing	CR		
	Red-necked Stint	NT	Decreasing	NT		
	Lesser Sand Plover, Greater Sand Plover			VU		
	Red & Gray Plovers, Whimbrel, Ruddy Turnstone, Gray-tailed Tattler			NT		
Invertebrates	Great, White Palau Tree Snails	CR	Unknown		No restrictions; May be in PAs.	Poor (None). Small range, high endemism
	Palau Pandanus Tree Snail	EN	Unknown			
Plants	*Aglaia mariannensis* (Mesecheues)	VU	Unknown		No restrictions; Some in PAs	Fair - Ongoing work to identify range and population[6]
	Cycas micronesica	EN	Decreasing			
	Pericopsis mooniana (Nandu wood Amansis)	VU	Unknown	TH		
	Horsfieldia palauensis (Chersachel)	NT	Unknown			
	Parkia parvifoliola (Kmekumer)	VU	Unknown	EN	Central pop. in PA	Fair - Restricted to 1 pop.; fire and IAS
	Palau Palm (*Ponapea palauensis*) (Esebuuh); Rock Island Palm (*Hydriastele palauensis*) (Bochelauchererak); *Timonius salsedoi*[5]			EN	No restrictions outside RISL	Fair - In RISL Managed Area
	Cinnamomum carolinense, C. pedatinervium (Ochod); *Xylocarpus moluccensis* (Demedemkur); *Garcinia matsudai* (Tilol); *Terminalia samoensis; T. crassipes* (Chesemiich); *Rhizophora x lamarckii; Ceriops tagal* (Biut); *Avicennia marina*			TH	No restrictions.	Fair - Ongoing work to identify range and population[5]

See footnotes, next page.

Overview of Responses and Gaps to Primary Pressures

SDG 15.2.1

Palau has a draft 2018 Sustainable Forest Management (SFM) Policy, which still needs to be adopted. Implementation of Sustainable Forest Management is an indicator under the Sustainable Development Goals (SDGs), particularly by tracking the amount of forest that is managed under long-term forest management plans. The draft SFM Policy calls for a "No Net Loss" approach to forests.

Palau has had a resurgence in effort going into sustainable forest management, driven by Protected Area Effective Management needs, Land Use Planning, Research (e.g. into land cover change and species), Birds, and Invasive Alien Species. This is a positive and necessary change given many years of minimal attention. Both of Palau's National GEF-funded projects include large portions focused on forests. Efforts to conserve, understand, and sustainably manage forests should continue.

Pressure	Primary Responses	Key Gaps
Fire	• Improved response to fire (by fire station personnel). • Effective Forest Restoration Methods research in Ngardok Nature Reserve, (e.g. application of 22.5 g/m² of fertilizer per foresting effort (Dendy et al. 2015)). • Research into fire and role in savannas and succession (Holm 2015).	• Compliance by the public with fire regulations, Best Practices, and Protected Area regulations. • Expanded forest restoration efforts • Other forms of fire prevention and suppression (beyond restoration).
Climate Change	• Terrestrial Protected Areas. • Identification of resilient areas and Best Practices for adaptation. • Expansion of Nursery capacity.	• Adaptation responses are slow. • Land Use Planning efforts are slow. • Forest health/PAN Monitoring is not yet fully implemented, data analysis is minimal. • Freshwater conservation and monitoring (quality, quantity) are minimal.
Invasive Species	• Multiple control, eradication efforts; with community, nonprofit, government, and international support. • Regional Invasive Species Coordinator Office in Palau. • Testing and employing biocontrols. • Research into controls and threats. • Implementation of NISSAP. • Identification and mapping, monitoring, compliance, and rapid response (GEF6).	• Implementation of GEF6 has just started. • Eradication or removal is very slow and time consuming; takes more person-days than possible. • Freshwater species and biodiversity is not monitored regularly.
Fungus	• Identification and mapping of infection loci.	• Removal and control of infected trees slow.
Unsustainable Human Use	• Protected Areas and Management.	• Little data on extent and type of human use, including where and what is occurring.
Other	• Update Palau Endangered Species Act (ESA) List • Identifying endemic, endangered plants, mapping extent and threats (Costion & Lawrence 2012; Costion 2013). • In 2009, 61% (>79) of endemic plant species were considered Data Deficient (by IUCN Red List standards). By 2013 an additional 16 species had been assessed (for distribution, abundance and/or species boundaries), reducing Data Deficiency by 20% (Costion 2013).	• Land Cover Change data, throughout Palau and particularly on Babeldaob, is old and incomplete. • Tracking systems to judge the extent and impact of development and clearing on forest are not well established (e.g. a system to tie earthmoving permits to land maps is still in development).

Addressing Pressures, Risks, and Gaps reported in the 2017 SOE

Fire remains a key primary pressure on forests. Clearing remains a pressure, but there is still little data or tracking of land cover change. The amount and availability of information on plants has improved drastically.

Regular monitoring of forests remains a gap, although it is improving particularly via PAN/Micronesia Challenge monitoring protocols. There is no publicly available monitoring data on freshwater quality or quantity.

[1] Global IUCN Red List Status as of March 2019. www.redlist.org. Trend as determined by the IUCN Red List as of March 2019. By order of threat: CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened.

[1] ESA = Palau Endangered Species Act, List of Threatened Species.

[3] Basis for Grade: Subjective. Good = Laws, regulations, and enforcement are adequate to stop local decline; Fair = Either laws or enforcement must be improved to stop local decline; Poor = No additional restrictions and/or species is in decline despite laws.

[4] SPREP (2016) identified at least 40 molluscs and 106 other invertebrates that were threatened, but did not distinguish by type (terrestrial, freshwater, marine). Many species that have not been studied; this should not be accepted as the total threatened invertebrates.

[5] Birds and *Timonius* sp. are Proposed 2018 ESA listings. All others from the previous ESA, which is still valid (Kitalong, pers. comm.).

[6] E.g., Costion (2013).

BIRDS

This section is written in loving memory of Alan Olsen, a dedicated advocate for biodiversity and birds in Palau.

Information for this section was kindly provided by the Palau Conservation Society, Ann Kitalong, or downloaded from eBird.

Birds are indicators of general environmental health. Birds appear to be doing better, with the significant investment in birds over the past decade leading to some improved Conditions and Trends.

State of Birds

After a decade of implementing bird programs, bird diversity is good, and Biib and Bekai may be on the road to recovery. Belochel trends are unclear; they are still being poached. However, Melabaob has decreased.

Pressures on Birds

As key indicator species, birds are vulnerable to multiple pressures. While Climate Change is a threat to birds, the majority of pressure on birds comes from humans.

Responses for Birds

There are many excellent programs (eradication, training, enforcement, research) for birds, and these have resulted in the improving Conditions. However, there is inadequate protected area for birds, and a critical shorebird site is not protected. Data access is good, but data are not always standardized or analyzed.

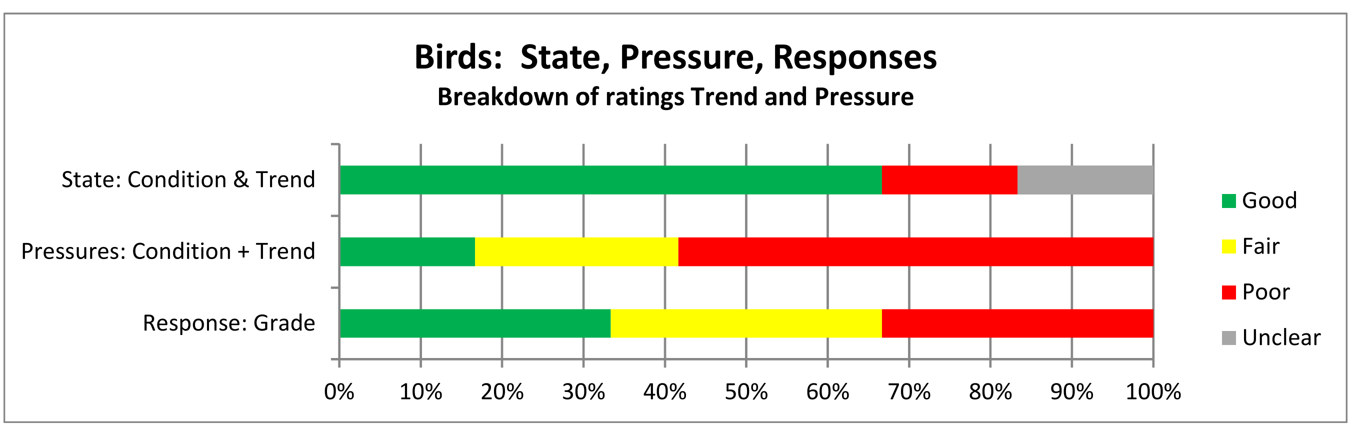
See Indicator 76 for endangered birds.

Addressing issues in the 2017 SOE

Some species may be in recovery, likely as a result of awareness, enforcement, and PAN. Investment into bird and forest conservation should continue.

The State of the Birds Report still does not track repeated variables. It should track indicator species (Belochel, Biib, Melabaob, Bekai) as well as endangered birds over time.

eBird data are accessible and useful, but not standardized. There are no new population estimates (surveys are scheduled).



SOE Indicator 77. Bird Diversity

Bird Diversity appears to be stable, although methods have changed and it is not possible to compare data directly. Information is included here anecdotally and to establish a new Baseline. Data here use both National Program for Monitoring Forest and Coastal Birds data and crowdsourced data. Both types of data are available (and not always distinguishable) on eBird, an online data sharing platform (https://ebird.org/region/PW) (accessed April 2019).

In these locations, the suite of expected Native Resident Bird species have been recorded at least once in 2017-2018 on eBird.

This 2019 SOE recommends putting a "Watch" status on this indicator, and recommends that the Palau Bird Records Committee determine methods to monitor change in diversity over time using the available eBird data, as well as include this Indicator consistently in the annual State of the Birds report.

	State (km²)		Trend	Condition[10]
Location	*Baseline*	*Recent (Cannot be directly compared) New Baseline*	*Apparent*	*Apparent*
Ngermalk/ Long Island	2007-2008[1] • 24 Resident • 3 Introduced; 18 Migratory 2010-2014[2] • Average=15 native spp./survey	2018[1] • 21 Resident • 5 Introduced; 5 Migratory 2018[3] • Average=14 native spp./survey	Appears to be Stable (Possible decline and spread of IAS)[7]	Good
Rock Islands	2011-2015[4] • 35 native resident	2017-2018 • 35 native resident	Stable	Good
Ngardok	2011-2015[5] • Average=12.4 native residents	2015-2018[6] • Average=9.8 native residents	2011-2018[8] Unclear; 2015-2018 (Figure I77)[9] Stable	Good
Ngeremeskang	2011-2015[5] • Average=13 native residents	2015-2018[6] • Average=12.1 native residents		Good
Mesekelat	2011-2015[5] • Average=10+ native residents	2015-2018[6] • Average of 8.0 native residents		Unclear (Good/Fair)

[1] Horii and Eberdong (2018)
[2] BNM (2014-State of Birds). Reported in 2017 SOE.
[3] Calculated from monthly table in Horii and Eberdong (2018), by subtracting IAS and migrants from total species observed.
[4] Olsen et al. (2016). Reported in 2017 SOE.
[5] BNM (2015, unpublished report to PAN). Reported in 2017 SOE.
[6] Data from eBird (April 2019). Number of species recorded per survey by Alan Olsen or Milan Eberdong, at locations listed as "Ngardok, Ngeremeskang, or Mesekelat" or clearly comparable. Data cannot be compared directly. 2015-2018 data included here in order to establish a new baseline using available records on eBird.
[7] Horii and Eberdong (2018) included the baseline data and noted the possible decline, but also noted that surveys may not be the same in terms of tidal cycle (thus influencing migrants), time of day of survey, or methods. Future researchers should watch for a possible decline in Native Resident Bird species and should watch for expansion of range of Introduced birds.
[8] Additional analysis is needed to determine the long-term trend, if the original data from 2011-2015 can be compared with data on eBird (2015-2018) at all. There are more records on eBird for 2017 and 2018 than for 2015 and 2016.
[9] While fluctuating significantly, Figure I77 suggests that over the long term, the average number of bird species recorded per survey is stable.
[10] A national threshold for diversity was set in BNM (2014-State of Birds), at 10 native resident bird species. 10 species present is the minimal acceptable threshold for healthy/expected diversity.

Photo © Shutterstock/Kazzazm

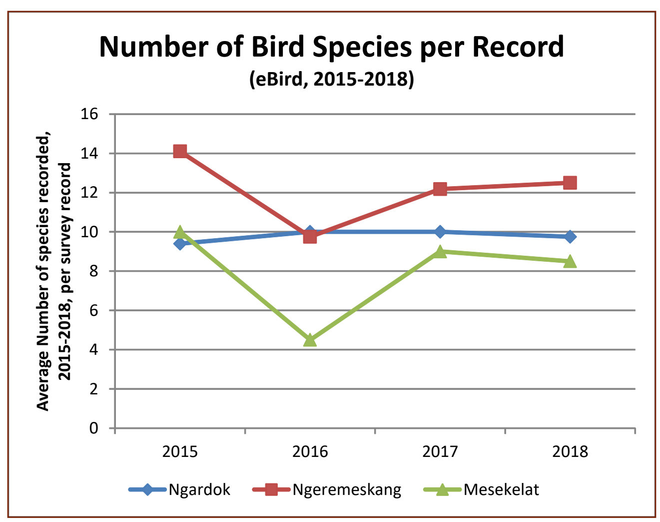


Figure I77. Bird diversity over time, indicating possible stability. Calculated from a selected subset of data on eBird (accessed April 2019), limited to survey records posted by Milan Eberdong or Alan Olsen (or accompanying associated surveying at the same time), and averaged per year.

SOE Indicator 78. Belochel (Micronesian Imperial Pigeon)

The Belochel trend is not clear (see Table and Figure I78). Several members of the Palau Bird Records Committee (PBRC) conclude that Belochel are still in decline (Eberdong and Kitalong pers. comm. 2019). However, Citizen-Science eBird data suggests that Belochel may have started to recover, at least since 2015. This 2019 SOE uses data through 2018, the 2017 SOE used data through 2014; data collection and reporting methods vary widely. The trend will be confirmed next year, when a repeat National Bird Survey using US Fish and Wildlife (USFWS) methods is conducted. Poaching and consumption (including by leaders) is known to occur.

Data from 1991 and 2005, used to generate population and Birds/Station estimates, were collected using USFWS methods, by trained observers, using an 8-minute count per station. Data were scientifically rigorous and comparable, but hard to use.

eBird Data and limits

Data from 2010 are available on the eBird website, a crowd-sourced data repository. eBird is where Palau's resource managers are storing much of their data, including "official" quantitative monitoring data (e.g. 8-minute counts through the National Program for Monitoring Forest and Coastal Birds (NPMFCB)), as well as qualitative counts by the NPMFCB, and casual observations by locals or visitors to Palau (Citizen Science).

eBird data were cleaned and analyzed in multiple ways (see "scenarios" in Figure I78) for analysis, but even the NPMFCB data are not coded in a standardized way, which creates a limit to analysis. This Report recommends that the "official" monitoring data collected by the NPMFCB (and partners such as Koror State) be coded into eBird using standard, repeated tags (e.g. Station Number, 8-minute count, etc.).

	State				**Trend**
Data type	*1991*	*2005*	*2010*	*Recent*	*2010-2018*
Birds Per Station: 1991 and 2005 (USFWS) 2014-2017 (National Program)	1.5 birds/station[1]	0.75 birds/station[2]		Cannot be directly compared	No clear trend
	Stations marked 8-minute count (N=20), removing 4/15/2016 pulse[5 6] 2014: 3.65 2015: 2.1 2016: 1.88 2017: 2.8 birds/station				
8-minute counts (Red line in Figure I78), pulse on 4/15/2016 removed 1. Birds per minute (limited to data entries labeled "8-minute count"). N=20 (Small sample, some years only 1-2)[6]					Decreased
Citizen-Science Bird observations, all and limited by observers, (Figure I78), with a pulse on 4/15/2016 removed[5] 1. Birds per record (all observers and observation types). N=756 2. Birds per minute (all observers and observation types) . N=756 3. Birds per minute (limited to data entries by Olsen and Eberdong). N=129					Increased

[1] Engbring (1992). 1991 Bird Survey. Reported in 2017 SOE.
[2] Birds per station from VanderWerf (2007).
[3] Ketebengang and Gupta (2011), data from VanderWerf and Olsen.
[4] eBird data, limited to monitoring data.
[5] Pulse on 4/5/2016 considered an aberration due to drought. Birds/station calculated from limited data (8-minute count), by first estimating number of stations ("Duration Minutes" divided by 8) and then dividing the "Observation Count" by number of stations; averaged.
[6] N=20. 6 records for 2014, 11 for 2015, 2 for 2016, 1 for 2017. Includes multiple observers. Limiting by observer removes years.

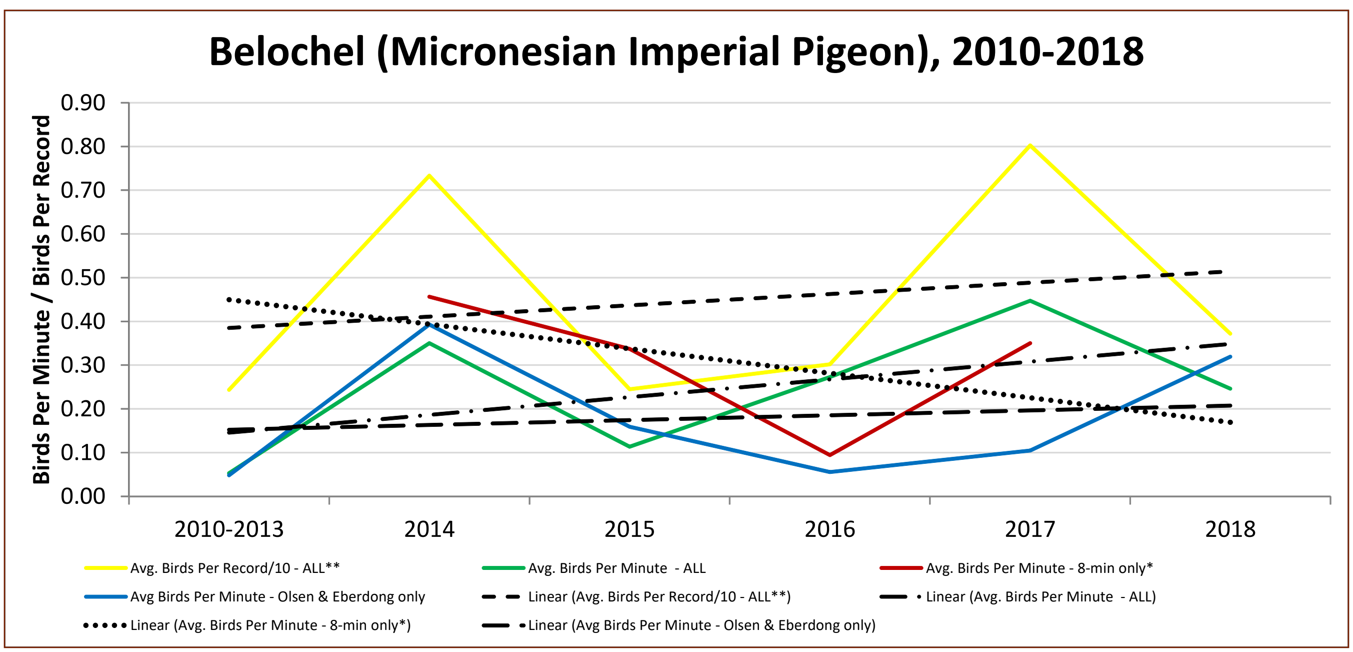


Figure I78. Trends in Belochel, indicating no clear trend. Calculated from a subset of data on eBird (accessed April 2019).
* Limiting to cleaned 8-minute counts creates a small sample size.
** Birds per Record reduced by 10x in order to fit onto the figure. Actual birds recorded per record are 10 times higher. Trend line is consistent.

SOE Indicator 79. Biib (Palau Fruit Dove)

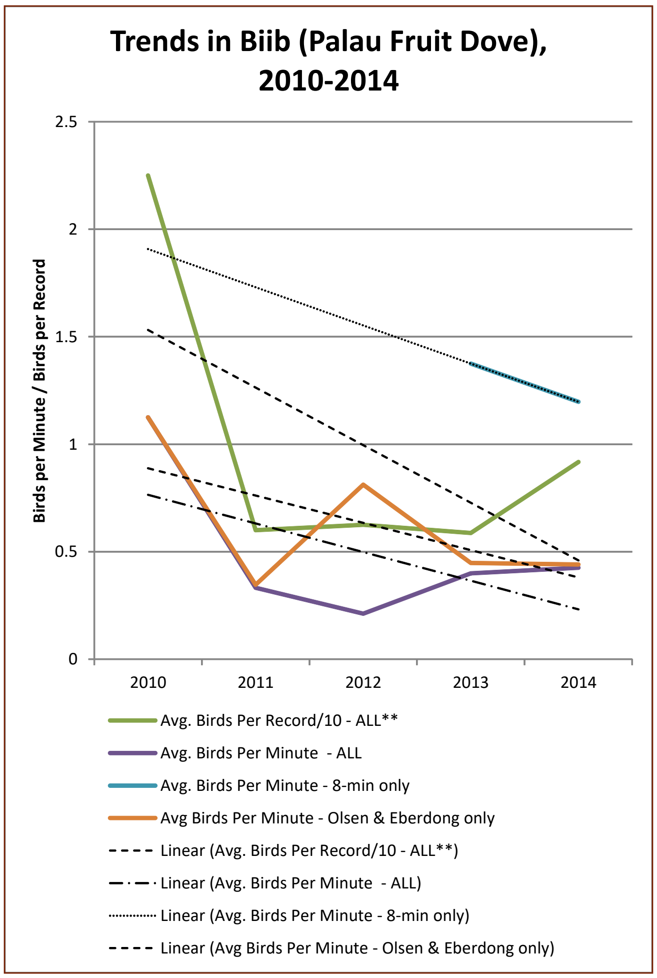
The population of Biib may be stable or increasing. This tentative conclusion is made with the caveat that data collection has varied widely over the years; however, under every scenario (Figure I79b), indicators for Biib trend upwards or are stable since 2015. Between 2010-2014, Biib decreased by 46 to 66% (BNM 2015; reported in 2017 SOE).

Although the BNM (2015) data was analyzed using different methods, the decrease reported there is consistent with multiple scenarios using 2010-2014 data from eBird (Figure I79a, from eBird). Thus Figure I79b (2015-2018) indicates that the declining trend in Biib has stopped or even reversed. See Indicator 78 for a discussion of eBird data and its limitations.

	State		**Trend**
Data type	*2010-2014*	*2015-2018*	*2015-2018*
Population/Frequency of Biib	• Population decline[1] • Decrease in frequency[2]	• Stable or Slight increase in frequency[2]	Stable or Increased

[1] BNM (2015). Reported in SOE.
[2] Calculated from eBird data, using the same scenarios as in Indicator 78:

1. Birds per record (all observers and observation types). 2010-2015, N=195; 2015-2018, N=1,915
2. Birds per minute (all observers and observation types). 2010-2015, N=195; 2015-2018, N=1,915
3. Birds per minute (limited to data entries labeled "8-minute count"). 2010-2015, N=14; 2015-2018, N=32
4. Birds per minute (limited to data entries by Olsen and Eberdong). 2010-2015, N=165; 2015-2018, N=283
5. Birds per minute (limited to data entries by Olsen and Eberdong, divided by the number of observers). N=131



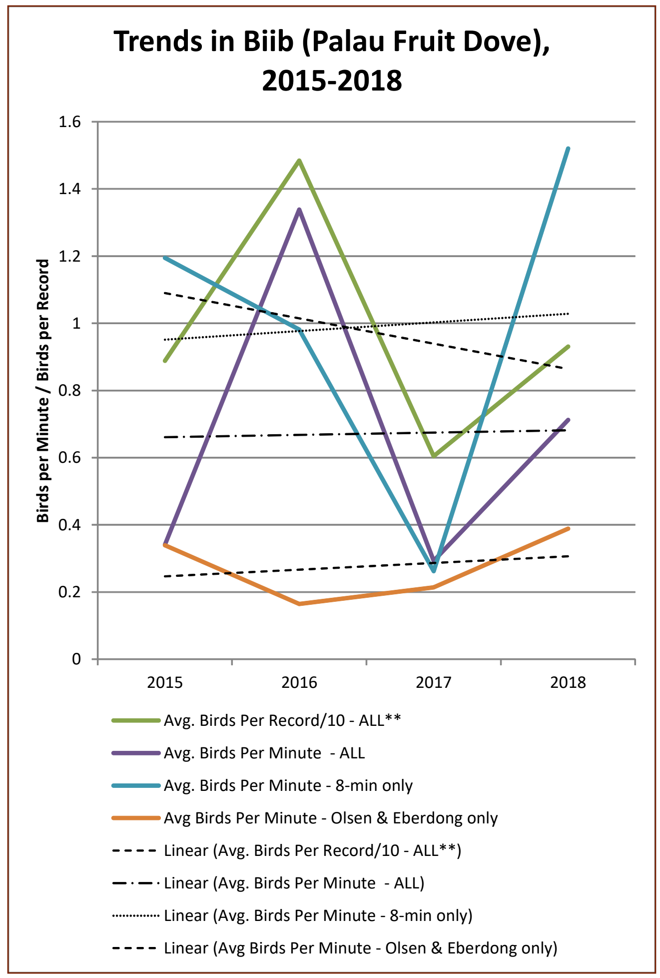


Figure I78a (left, 2010-2014) and I79b (right, 2015-2018). Trends in Biib under a variety of scenarios. Figure I78a (2010-2014) appears to align with confirmed decrease reported in BNM (2015). Figure I79b (2015-2018) suggests a stable or increasing trend across most scenarios. The one declining trend is calculated using all available data, including those from casual observers and visitor to Palau; thus it has low confidence. Calculated from a selected subset of data on eBird (accessed April 2019).
** Birds per Record has been decreased by a factor of 10 in order to fit onto the figure. Actual birds recorded per record are 10 times higher. Trend line is consistent.

SOE Indicator 80. Melabaob (Rufous Night Heron)

Olsen and Eberdong (2014) established Melabaob as an indicator of coastal health. In 2012 they set a baseline of 12 birds/count. Melabaob were found almost exclusively on exposed seagrass meadows at low tide. Indicator 32 shows that seagrass has decreased.

Using data from eBird, under multiple scenarios it appears that Melabaob has decreased since 2012 (Figure I80). See Indicator 78 for a discussion of eBird data and its limitations.

	State			Trend
Data type	*Baseline*[1]	*eBird (Birds per Record)*[2]		*2012-2018*
Birds per record / Birds per count	2012: 12 birds per count	2012: 20 2013: 14 2014: 9 2015: 10	2016: 12 2017: 8 2018: 11	Decreased

[1] Olsen and Eberdong (2014).
[2] Avg. Birds per Record. Calculated from eBird (limited to data entries by Olsen and Eberdong), by averaging the total number of birds recorded per entry.
[3] Calculated from eBird, using the same scenarios as in Indicator 78:
1. For ALL, N=1,048.
2. For Olsen and Eberdong, N=759

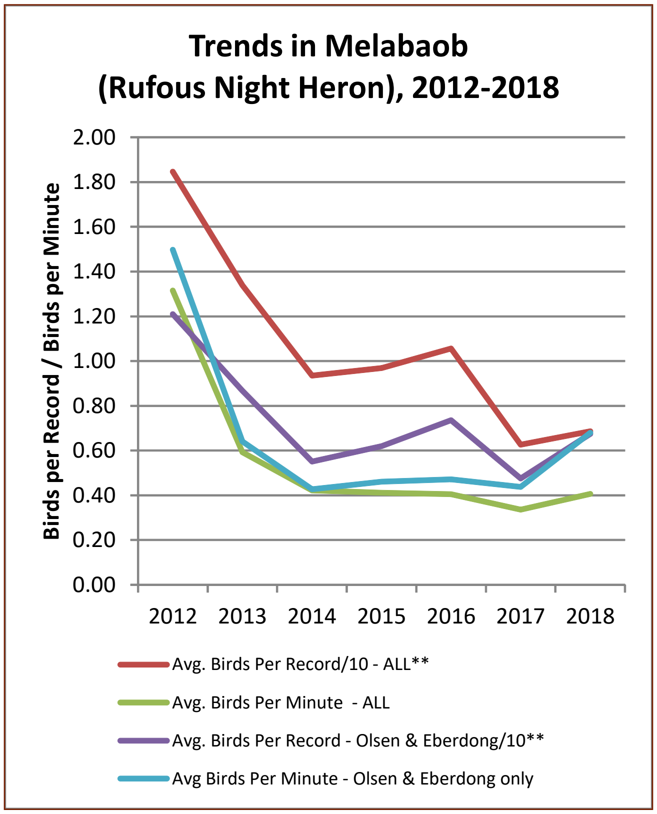


Figure I80. Trends in Melabaob under a variety of scenarios, showing likely decrease. Calculated from a selected subset of data on eBird (accessed April 2019).
** Has been decreased by a factor of 10 in order to fit onto the figure. Shape of curve is still correct.

SOE Indicator 81. Bekai (Micronesian Megapode)

eBird data indicates that Bekai increased since 2014 (Figure I81). However, there is no comparable data to 2005's National Bird Survey. See Indicator 78 for a discussion of eBird data and its limitations. There are several pressures facing the species.

	Trend
Data type/Location[1]	*2005-2018*
Birds per minute - ALL, all locations; N=571	Increased
Birds per minute - Kayangel - ALL; N=5	Increased
Birds per minute - Koror - ALL; N=452	Increased
Birds per minute - Peleliu - Limited; N=24	Increased

[1] Avg. Birds per Minute. Calculated from eBird, using all entries except for Peleliu (labeled entry excluded).

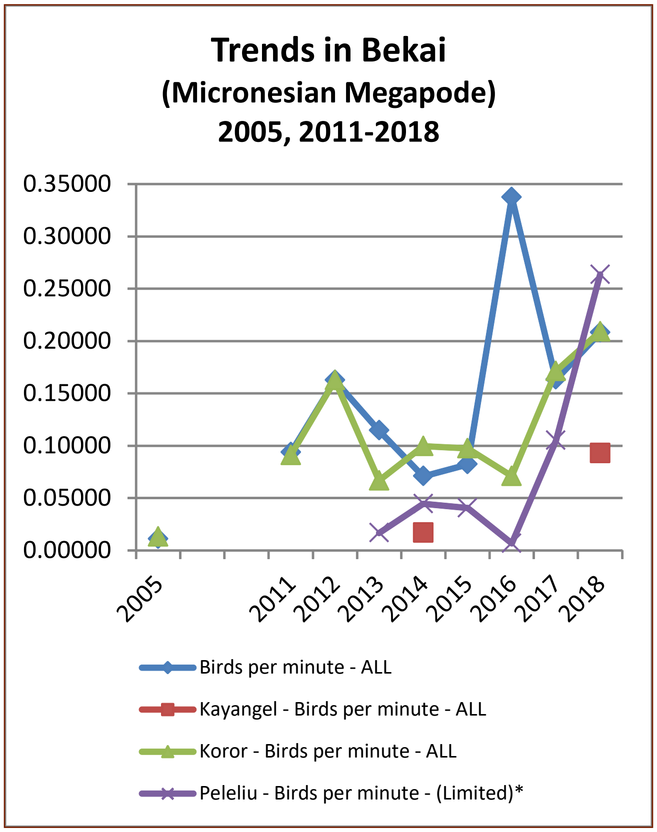


Figure I81. Trends in Bekai, by location. Calculated from a selected subset of data on eBird (accessed April 2019).

SOE Indicator 82. Omekrengukl (Palau Ground Dove)

Omekrengukl/Doldol appears to have decreased, although there is very little data available. The bird was not observed at all during monthly monitoring surveys of the Rock Islands Southern Lagoon in 2017-2018 (Horii 2018). Zero (0) were observed on Ulong Island, where in 2005 they were "easily observed" (VanderWerf 2007). In 1991 there were 0.15 birds/station (Engbring 1992) but in 2005 there were only 0.006 birds/station (VanderWerf 2007). On eBird there are only 53 total records, and there are many months with zero (0) sightings.

Overview of Pressures on Birds

(See Indicator 76 for Endangered and Threatened birds.)

Climate Change	Invasive Species	Poaching and Harassment	Habitat Loss & Degradation
Indicator 83	Indicator 84	Indicator 85	Indicator 86

SOE Indicator 83. Climate Change Pressures: Storms, SLR, Variability

Palau's birds are vulnerable but appear to be resilient to pressures from Climate Change.

Sea Level Rise (SLR)

A thorough, 2-year survey of Micronesian Megapodes (Bekai) and their nest mounds (from Kayangel to Peleliu) found that 97% of active nest mounds were less than 5 meters above sea level. On Ngeanges island in the Rock Islands, 1 of 4 nest mounds had been inundated by surge during Typhoon Bopha. A year later that nest mound was still abandoned as its original location was under water during high tides (Olsen et al. 2016). Radley (2019) modeled SLR and predicts that Bekai will lose 33-43% of their known breeding habitats by 2100.

Typhoons and Storms

A survey in January 2013 immediately after Typhoon Bopha found that on the east coast of Ulong island, 2 out of 2 (100%) active megapode nest mounds had been completely washed away and zero (0) megapodes were observed. Eight months later there was still no megapode activity. It was not until 2015 that forests on Ulong recovered and megapodes and active nests were observed again (Olsen et al. 2016).

Indicator 32 showed that in monitored sites, seagrass cover decreased by 30 to 50% after typhoons, and had not yet fully recovered. A decrease in seagrass may be associated with the downward trend of Rufous Night Herons (Melabaob).

Rainfall/Temperature Variability

100% of active megapode nest mounds were in fully shaded locations (Olsen et al. 2016). Drought, increasing rainfall, and increasing temperatures may reduce forest cover or health, and subsequently negatively impact megapodes. Changes in fruiting seasons and abundance (Indicator 69) may negatively impact forest birds.

SOE Indicator 84. Alien Invasive Species

The impact of Alien Invasive or Introduced species on birds is known to occur but not quantified. Invasive birds may outcompete native birds. Invasive plants, particularly vines, may damage forests enough to have an impact on bird populations.

Horii (2018) speculated that the lack of Palau Ground Doves (Indicator 82) at Ulong island may be due to predation by cats or rats. Megapode populations have benefitted from rodent eradication and cat control on Kayangel and in the Rock Islands. Angaur has the lowest bird diversity of all the forested islands in Palau, likely due to the presence of macaques (Miles 2017 in Rengill et al. 2017). Olsen et al. (2016) inspected the stomach contents of two Monitor Lizard carcasses, and did not find any evidence that birds were ingested. Radley (2019) found no significant relationship between rats and megapodes in the RISL.

SOE Indicator 85. Poaching & Harassment

Poaching of Micronesian Imperial Pigeon (Belochel) and Megapode (Bekai) eggs is known to occur but not quantified. One 2015 record in eBird noted finding a Pigeon that had been "killed." Indicator 68 suggests that hunting continues in Protected Areas. In Melekeok, 64% of respondents to a socioeconomic survey (Marino and Jonathan 2018) agreed with the statement "I often see or hear about illegal entry or taking of resources from the Conservation Area(s)."

Radley (2019) detected significantly more megapodes on tourist-free islands than on visited ones. During surveys of the Rock Islands, Koror State Conservation and Law Enforcement staff found a juvenile White-tailed Tropicbird that had died in its nest. Horii (2018) reported that "tourists sometimes harassed the bird."

SOE Indicator 86. Habitat Loss and Degradation

All of Palau's endemic birds are dependent on forests at some point in their life cycle. Thus, loss or degradation of forest will have negative impacts on bird populations. Important Bird Areas and bird habitats are not adequately protected enough to prevent habitat loss and degradation (Indicator 87).

Horii (2018) noted that on Ulong island there was little remaining vegetation in the beach area, perhaps explaining the lack of Palau Ground Dove.

Using six years of data from the National Program for Monitoring...Birds—2787 data entries from 14 inhabited beach sites from Babeldaob to Peleliu—Olsen et al. (2016) found zero (0) records of megapode activity on any inhabited beach. Olsen et al. (2016) also found that megapodes left an area of Ngerechong island after it had been completely "cleaned" (including removal of forest canopy) after Typhoon Bopha. Previously there had been three (3) active nests.

SOE Indicator 87. Protected Bird Areas

SDG 15.1.2

35% of Important Bird Areas (IBA; not including Marine IBAs) are protected, which is 44% of the way to the target (Indicator 73). 26% of shorebird sites are protected (green on Figure I87), however, the most important sites for Endangered resident and migrant Shorebirds (such as Northern Peleliu Lkes IBA) are not protected (BNM 2017-State of Birds). PAN Sites have implemented standardized Bird Monitoring, and training is offered.

Overview of Responses and Gaps to Primary Pressures

Palau has a very strong conservation programs for birds, with regular monitoring by a cadre of trained resource managers and citizen scientists. Where Palau has invested attention (e.g. eradication programs and mapping for Bekai; awareness, training, and enforcement for Belochel), there has been conservation success.

Primary Pressure	Primary Responses	Key Gaps
Climate Change	• Protected Areas (PAs). • Strong ongoing monitoring programs, with training • Research and monitoring of birds, e.g. banding shorebirds and translocating and caring for Megapodes. • Documenting High Priority Areas.	• Fire remains a problem in PAs (Indicator 68). • Inadequate protection of shorebird habitat. • No clarity on best response following a storm (e.g. clearing/cleaning of tourist sites).
Alien Invasive Species	• Active rodent eradication programs and cat control on multiple islands, with partnerships and follow-up. • Ongoing IAS plant removal programs. • Development and Implementation of Megapode Conservation Action Plan.	• Follow-up monitoring after eradications. • Biosecurity is still in development (e.g. possible re-introduction). • Need Conservation Action Plans for other Endangered Species (Indicator 76).
Habitat Loss and Degradation	• 35% of IBAs (mostly forested) are protected. • Some shorebird sites are protected as parts of MPAs. • Ongoing land use planning efforts.	• Northern Peleliu Lkes IBA not protected. • Protected Shorebird sites have low Conservation Priority Scores. • Degraded lands (Indicator 65).
Poaching and Harassment	• Protected Areas. • Training programs for PAN Officers. • Awareness programs.	• Poaching of Belochel and consumption (including by leaders) • Known demand for regulated species. • Inadequate surveillance, enforcement, and prosecution.
Multiple	• Establishment of the Palau Bird Records Committee (PBRC) with set procedures and ByLaws, as the nation's premier authority on birds. • Excellent information on birds, annual reports. • Adoption of bird monitoring protocol by PAN. • National Law prohibiting taking of all birds (minus four exclusions). • Accessible and shared data, high involvement of the public and citizen scientists.	• Continual increase in number of Birds on the global endangered species list (Red List) and slow but continual increase in their threat categories (Indicator 76). • Northern Peleliu Lkes IBA is home to endangered megapodes (BNM 2016-State of Birds) and endangered Migratory Birds. • Monitoring data not analyzed frequently, not always standardized.

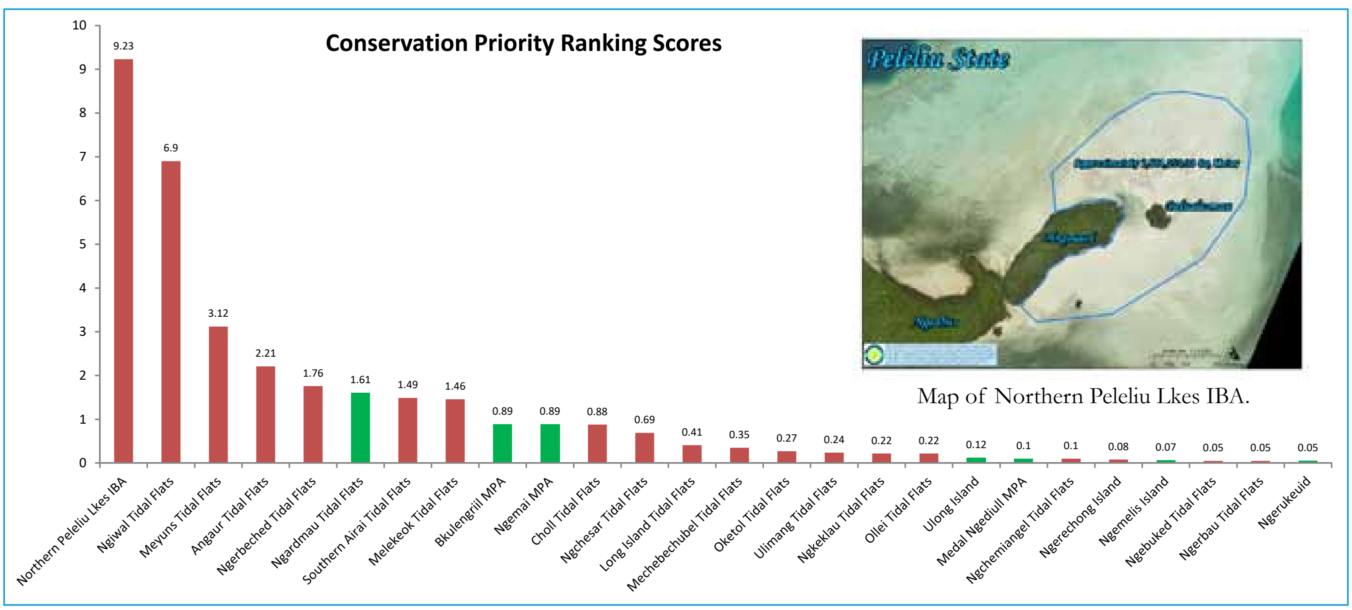


Figure I87. Standardized Conservation Priority Scores for coastal sites based on shorebird diversity. The calculated score is weighted toward rare species such as endangered migratory shorebirds. Figure from BNM (2017-State of Birds). Green bars represent protected sites. *Inset:* With the highest score, the Northern Peleliu Lkes Important Bird Area is the highest priority site for shorebird biodiversity conservation in Palau. Inset figure by PALARIS, courtesy of PCS.

Earthmoving & Development

The information for this section was kindly provided by the Environmental Quality Protection Board (EQPB) and the Palau Automated Land and Resource Information System (PALARIS).

State of Earthmoving and Development

The number of permits issued continued to increase, with few land use plans guiding development. Both the number of violations and the violation rate increased. Exemptions in the EQPB Regulations mean that the majority of development is permitted without a formal Environmental Assessment (EA) or Environmental Impact Statement (EIS).

The majority of hotel growth since 2012 has been small/niche.

Responses associated with Earthmoving and Development

EQPB continues to review and revise its regulations, and as part of a GEF6-funded National Project will review exemptions to ensure that environmental impacts from earthmoving and development projects are properly mitigated and assessed. The project will also support landscape/seascape and land use planning. EQPB's appropriation increased to over $500,000. In 2017, no (0) states had comprehensive landscape and seascape plans in place; 4 of 16 states have partial plans or at least some zoning (Koror, Airai, Melekeok, and Ngardmau).

SOE Indicator 88. Earthmoving Permits

The clear increasing trend in Earthmoving Permits continued (Figure I88a), driven by increases in commercial and residential development (Figure I88b). Note that total permits include those for existing structures (e.g. renovations and extensions).

	State[1]	Trend
Number of Permits	2018: 316 Highest recorded	Increased (Color code for environmental impact only)[2]

[1] EQPB (2018) and Quarterly economic indicators (ROP 2017-2018).
[1] Golbuu et al. (2011) found that river sediment yield, reef sedimentation rate, and reef turbidity increased strongly with increasing numbers of earthmoving permits.

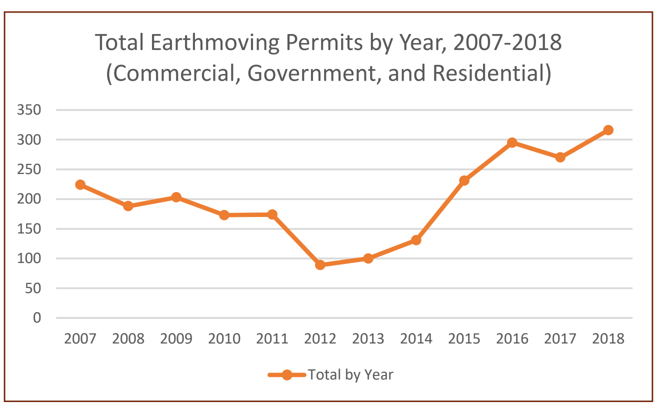


Figure I88a. Total number of Earthmoving Permits issued by Year. Graphed using data in EQPB (2016, 2018) and Quarterly Economic Indicator reports (ROP 2017-2018).

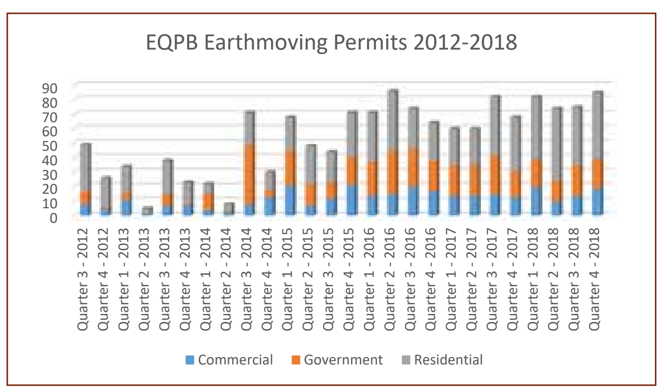


Figure I88b. Earthmoving Permits issued by quarter and type.

SOE Indicator 89. Type of Earthmoving Permit /Land Affected

Government and Commercial development affects larger parcels of land and has had/may have more environmental impact than Residential development, especially compared to individual homes. 2017-2018 saw slightly fewer government and commercial permits issued.

	State[1]	Trend
Number of Government and Commercial Permits	2013-2014: 127 2015-2016: 297 2017-2018: 280	2013-2018 Increased 2017-2018 Decreased
Percent Commercial and Government (combined)	2013-2016: 56% 2017-2018: 48%	Decreased

[1] EQPB (2016, 2018), and 2017 SOE

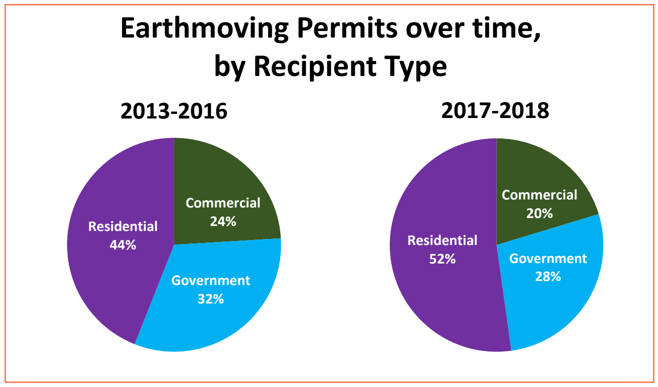


Figure I89. Percent of Earthmoving Permits in two different time periods by type of recipient. New data from EQPB (2018).

SOE Indicator 90. Violations/Violation Rate

The number of Notice of Violations (e.g. violation to permit conditions or unpermitted) increased (Figure I90). This may be due to the fact that EQPB secured a full-time Legal Counsel to pursue violations, or a rapid push to develop.

	State[1]		Trend
Number of Notice of Violations	2014: 10 2015: 13 2016: 46	2017: 36 2018: 49	Increased
Violation Rate	2014: 8% 2015: 6% 2016: 16%	2017: 13% 2018: 16%	Increased

[1] EQPB (2016, 2018), and 2017 SOE

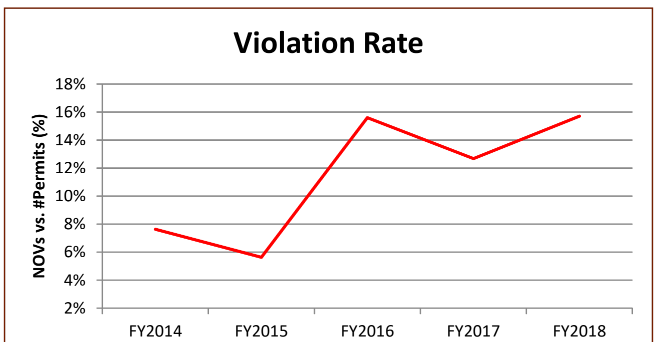


Figure I90. Number of violations versus number of permits (%).

SOE Indicator 91. Environmental Assessments/EA Rate

The number and percent of earthmoving projects requiring an Environmental Assessment (EA) has been stable (Figure I91); however, this has allowed projects to occur with negative environmental impact. Environmental regulations and guidelines for triggering EAs for earthmoving projects are ambiguous, resulting in a large number of projects being exempted. Specific EA exemptions include single or family homes, "small" developments (including farms and buildings with 4 rooms or less), and upgrades to existing facilities. The EA requirement is also at the discretion of the Board. Exemptions and inconsistencies in the application of EA requirements has resulted in fewer projects considering environmental impact through an EA than is environmentally desirable. Not all EAs require or receive public comments.

	State	Trend
EAs	Number = 21-22 Percent (2015-2018) = 6-7%	Stable

[1] EQPB (2016, 2018), and 2017 SOE

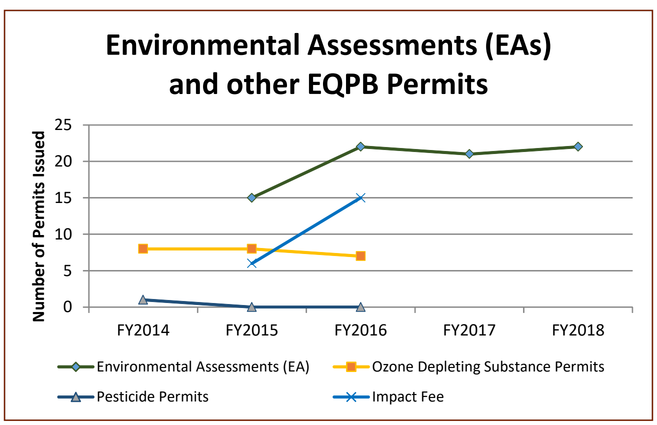


Figure I91. Number of EAs required as part of earthmoving permit.

SOE Indicator 92. Koror Building Permits

Building permits issued by Koror State have decreased and are fewer in number than earthmoving permits issued by EQPB. This suggests that most development is outside of Koror. In 2017-2018 Koror issued 102 building permits; EQPB issued 586 (1:6). In 2013-2014 Koror issued 108 building permits; EQPB issued 231 (1:2).

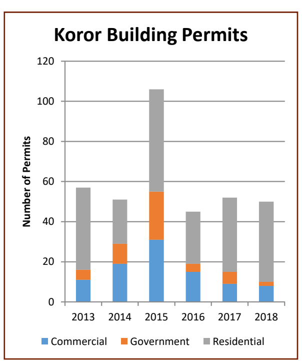


Figure I92 (left column). Number and type of Koror building permits. 2017-2018 permits: 75% residential, 17% commercial, 8% government. 2013-2014 permits: 62% res., 29% comm., 15% gov.. Graphed from data in Quarterly Economic Indicator reports (ROP 2017-2018).

SOE Indicator 93. Visitor Accommodations, Number of Hotels/Motels

The number of hotels, motels, and accommodations has increased since 2012, although much of that growth has been in smaller establishments, but still largely in Koror and Airai (Figure I93a). In 2012 there were 45 hotels/motels (BBP 2017) while in 2019 there were 95 hotels/motels (PALARIS 2019). The number of rooms grew from 1,330 in 2012 to 1,680 in 2017 (BBP 2017). In 2012 there were 32 establishments in Koror and Airai and 13 in other states (BBP 2017); in 2019 there were 77 in Koror and Airai and 18 in other states (PALARIS 2019). All hotels have been mapped (Figure I93b).

Type of Accommodation	*Number in Palau (2019)*
Bed & Breakfast	25
Cottages	19
Hostles	2
Hotels	36 (7 Large)
Motels	13

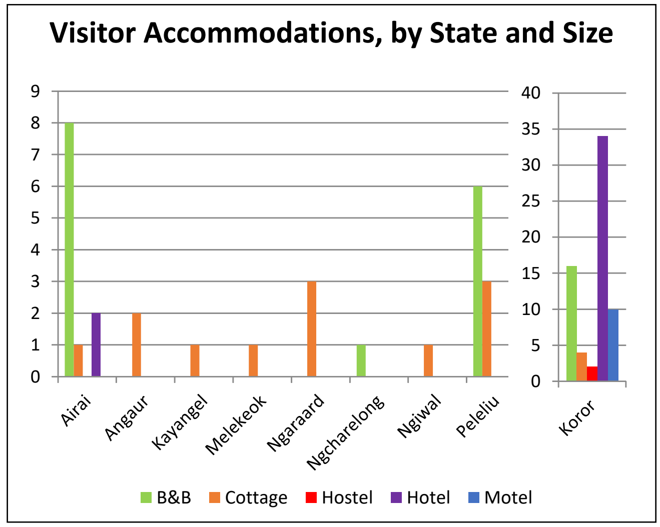


Figure I93a. Visitor accommodations by state. Graphed from data provided by PALARIS (2019).

Figure I93b. Map of visitor accommodations (all kinds) in Koror. Figure from PALARIS (2019).

Addressing Pressures, Risks, and Gaps reported in the 2017 SOE

Earthmoving continues to increase in scope and impact, although the government is catching up in terms of monitoring extent and impacts. PALARIS is finishing land use/land cover maps that will enable more accurate monitoring of impact. (All hotels and agricultural plots have already been mapped.) A GEF-funded project is building a database and data sharing and collection protocols and standards for PALARIS, EQPB, the Bureau of Agriculture, and the Bureau of Marine Resources.

Land use planning continues, and a GEF6-funded National Project will increase the number of States with the capacity to implement landscape and seascape plans.

Correction: There is fine-resolution bathymetry (p. 17).

Water Resources

Photo courtesy of BWA/R2R

The information for this section was kindly provided by the Environmental Quality Protection Board (EQPB) and gleaned from publicly available Palau Public Utilities Corporation (PPUC) reports.

State of Water

Treatment of drinking water and overall drinking water supply are good. Drinking water in the urban areas of Koror and Airai meets safe standards for Turbidity and E. Coli. However, water in the urban area exceeds standards for total coliform and rural areas exceed turbidity and coliform standards regularly. This 2019 SOE used updated and revised EQPB Regulations (2013), thus standards have been clarified. Water supply is good on an annual basis, but supply varies dramatically with extreme weather. Total use (and waste) may have decreased since 2010.

Responses associated with Water

Palau's drinking water monitoring program is excellent. However, there is inadequate monitoring or information on marine and freshwater resources (quality and/or quantity of freshwater). Access to treated water and access to sanitation are almost 100%. Improvements to water and wastewater infrastructure are likely contributing to decreased average Fecal Coliform and Turbidity; and to decreased water use (from less waste).

SOE Indicator 94. Water Supply and Usage (Koror-Airai)

SDG 6.4.1
SDG 6.4.2

Supply is expected to increase with increasing annual rainfall (Indicator 11); but with high variability (storm and drought events). The 2016 drought resulted in months of water shortages and rationing.

Water usage in Koror and Airai has been steady. PPUC reported sales ranging from 730,000 to 800,000 gallons/year between 2014 and 2017 (Figure I94). Residential sales increased; commercial sales decreased.

PPUC has been installing meters to better account for water usage, and significant infrastructure projects are reducing water losses from the system. According to PPUC, conservation programs and increased customer awareness has marginally reduced average customer consumption (PPUC 2017).

In 2010, estimated total demand for water in Koror and Airai was 1,460,000,000 gallons per year (Kitalong 2012); this included waste and inefficiencies. If water usage in Koror and Airai is now in the 800,000 gallon/year range, then it appears that water usage has decreased significantly since 2010.

State[1]	Trend
Annual supply	Likely increasing, with variability
Water usage	Steady (2014-17); Decreased (2010-17)

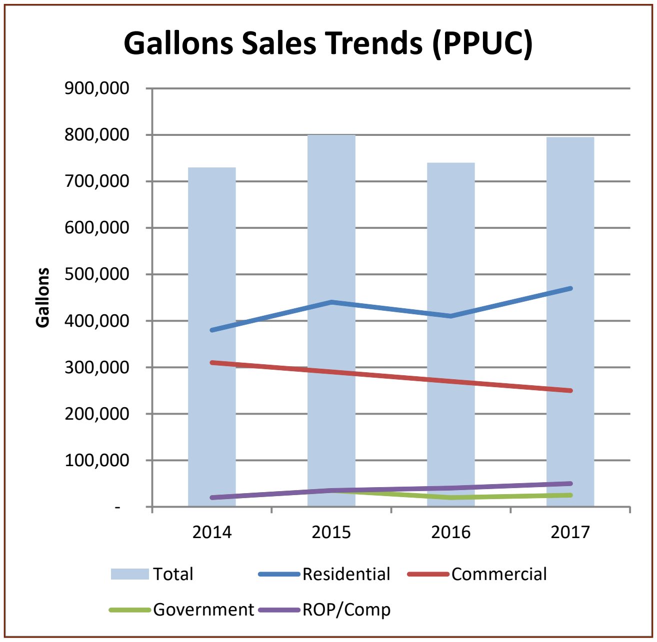


Figure I94. Water gallons sales by PPUC. Figure recreated from PPUC's Audit (2017); total sales estimated from figure in Audit.

SDG 6.1.1

SOE Indicator 95.

Drinking Water Coliform

Fecal Coliform decreased (Figure I95a) due to improvements to the Koror-Airai water distribution and wastewater collection lines; however, in 2018 the number of times coliform tested positive was not in compliance with EQPB's Regulations (2013). The more dangerous E. Coli was not found in the urban system. Total coliform was above the compliance threshold in all locations (see table). The number of samples tested increased in 2017 and 2018 (Figure I95b). Significant improvements were seen in several locations with positive Fecal Coliform in 2014-2016 (Figure I95c).

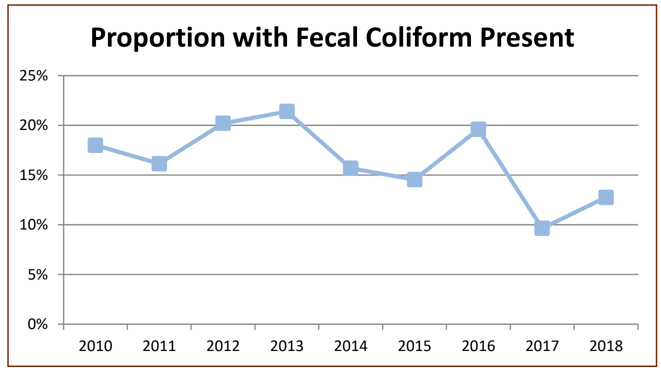
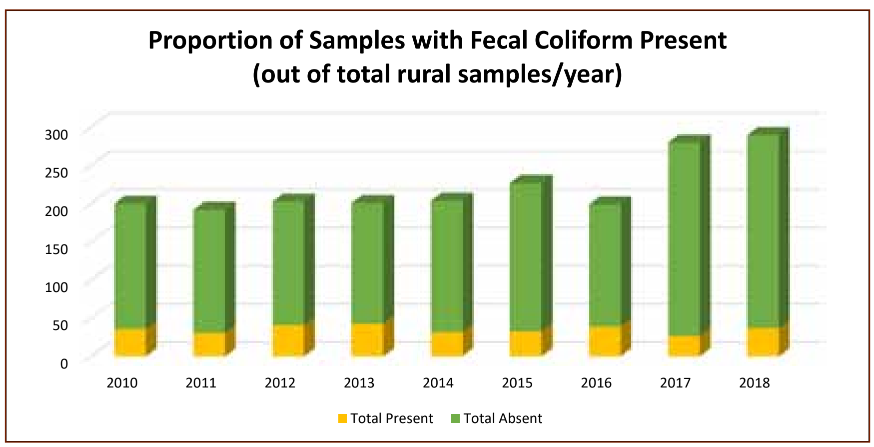


Figure I95a. Proportion of samples with Fecal Coliform present, Palau-wide (includes Koror-Airai). Data from EQPB (2019).

	State		**Trend**	**Grade**[4]
Data type	*Proportion with Presence*		*2010-2018*	*2018*
Proportion and Number with E. Coli Present	Koror-Airai Public Water System: 0		Stable	Good
	Rural Public Water Systems:[2] 2017: 10% (27 samples) 2018: 13% (37 samples)		Decreased	Not in Compliance[1] (4 states with repeat positive tests in 1 month)
	2017-2018 (Combined)[3]		**Grade**	
	Total Coliform	*E. Coli*	*Total Coliform*	*E. Coli*
Koror/Airai	8.0%	5.3% (Oikull)	Not in compliance (>5% / >1 per month)	Koror: Good Oikull: Poor
Hospital	14%	0%	Not in compliance[1]	Good
Rural States (Public Water)	15%	7%	Not in compliance[1]	Fair
Ngerulmud	64%	27%	Not in compliance[1]	Poor

[1] Estimate, as analysis here was done on yearly scale, not monthly scale; based on information in 2013 EQPB Regulations.
[2] Total, includes Oikull and Ngerulmud.
[3] EQPB (2019b-Summary Sheet).
[4] *Basis for Grade:* For those systems with less than 40 samples per month, no more than 1 positive Total Coliform test per month in order to be in compliance. For systems with more than 40 samples per month, no more than 5% positive Total Coliform tests to be in compliance.

Figure I95b (right). Number of rural samples taken per year, and percent with Fecal Coliform. Data from EQPB (2019).



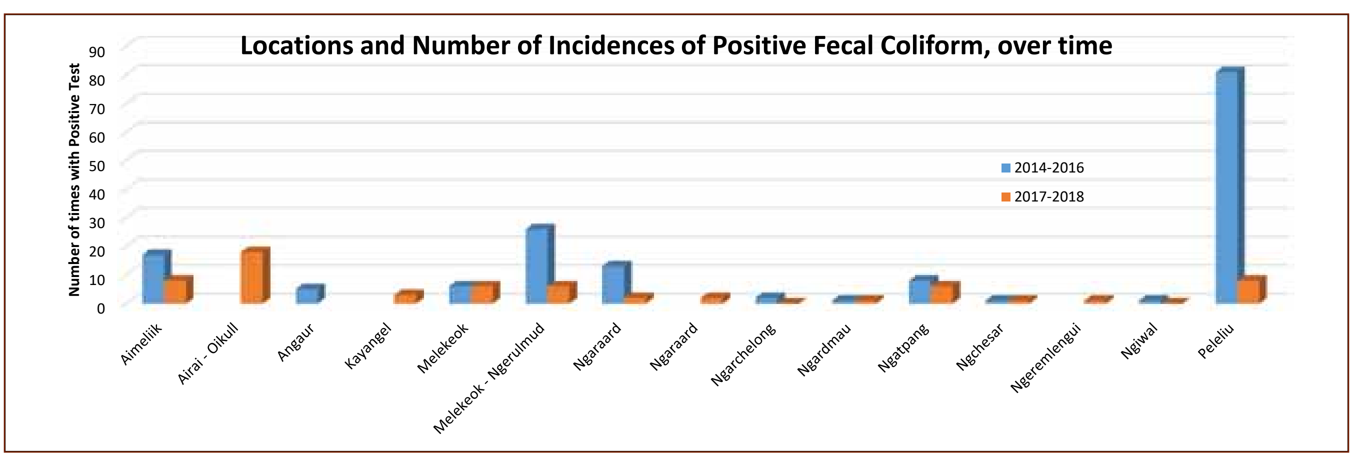


Figure I95c. Locations and incidences of Positive Fecal Coliform, over time. Data from EQPB (2019).

SOE Indicator 96.

Drinking Water Turbidity

SDG 6.1.1

Turbidity in Koror and Airai is good–far below allowed. The annual average indicates that turbidity is usually at acceptable ranges in rural areas (Figure I96), but daily variance may put a system out of compliance. The updated EQPB Regulations (2013) were used to determine the Indicator Grade here; old US EPA standards were used in the 2017 SOE and thus the Grade has been changed (for the same value (18%)).

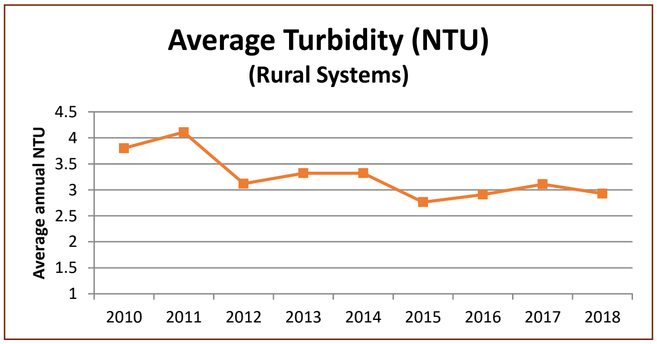


Figure I96 (right). Turbidity in rural systems. Data from EQPB (2019).

	State	Trend	Grade
Data type	*2010-2018*		*2018*
Annual average NTU, Rural Systems	2018: 2.93 NTU	Decreased	Good[1]
Daily NTU above 5 NTU, Rural Systems	2017: 53 out of 280 (19%) 2018: 51 out of 290 (18%)	Stable	Fair[2]
Annual average NTU, Koror	2017: Avg. 0.50 NTU 2018: Avg. 0.48 NTU	Decreased	Good[1]
Daily NTU, Koror	2003-2017: Range of 1-3 NTU 2017-2018: 0 readings above 5NTU 2017 Max=1.23 2018 Max=1.51	Decreased	Good[2]

[1] Below Maximum Allowed (At no time over 5 NTU). *Basis for Grade:* EQPB Regulations (2013).
[2] Estimate. More than 5% of samples are greater than 1 NTU, then not in compliance. Analysis here was done using 5 NTU threshold.

SOE Indicator 97.

Access to treated water

SDG 6.1.1

The number of households with access to piped, treated water increased. In 2015, 99% of Palau's households had access to piped, treated water. In Koror and Airai, only 14 households (out of 3,715) did not have access to piped water (2015 Census).

In 2017 zero (0) schools designated as Emergency Shelters had rainwater harvesting and filtration systems capable of providing safe water during emergencies (ABD 2018).

	State	Grade
Data type	*2010-2015*	*2010-2015*
Households with piped, treated water	2010: 90%[1] 2015: 99%[2]	Increased/ Good
School Emergency Shelters with rainwater harvesting and filtration	2017: 0[3]	Baseline

[1] Kitalong (2013). [2] 2015 Census, 2018 SDG Report.
[3] ADB (2018).

Addressing issues in the 2017 SOE

Marine water quality monitoring remains a gap, and there is no new information on sedimentation rates (thus proxies are used (Indicator 12). There is still inadequate information on freshwater supply, efficiency, demand, and total use (nationwide). Newer issues (e.g. saltwater intrusion into a freshwater lens) present action and information gaps.

SOE Indicator 98.

Access to Sanitation

SDG 6.2.1

Access to sanitation has improved and is near 100% across Palau.

	State	Grade
Data type	*2010-2018*	*2010-2018*
Proportion of population **without** access to sanitation	2006: 33% without access[1] 2010: 16% without access[1] 2015: 0.4% without access[2]	Decreased/ Good

[1] Kitalong (2012-MDG)
[2] 2018 SDG Report (6.2.1), Census and Statistical information.

SOE Indicator 99.

Marine and River Water Quality

EQPB monitors marine water quality in limited locations (see also Indicator 10 on Acidity).

A 2018 Environmental Assessment (EA) for the proposed Palm Springs Resort on Ngerur Island in Koror found zero (0) coliform bacteria and low turbidity (0.4-0.78 NTU). A 2018 EA for the Ngellil Nature Island Resort in Ngerusar, Airai, found coliform levels below acceptable (0-20 MPN/100ml) and turbidity of 0.8-2.1 NTU (above the Class A Standard). An EA by PECI around M-Dock in Koror found turbid waters in mangroves and on reef flats; water quality deteriorated rapidly in inclement weather.

River water quality is being monitored in Melekeok through a GEF5-funded Ridge-to-Reef (R2R) National Project in partnership with BWA.

Solid Waste & Recycling

Photo by A. Gupta

The information for this section was kindly provided by the Division of Solid Waste Management (DSWM), Bureau of Public Works (BPW).

State of Solid Waste and Recycling

The increase in total waste generated is outpacing programs to reduce, reuse, or recycle waste. Although solid waste programs are good, with collection in 100% of residential areas and numerous recycling programs, they are not able to keep up with the amount of solid waste produced.

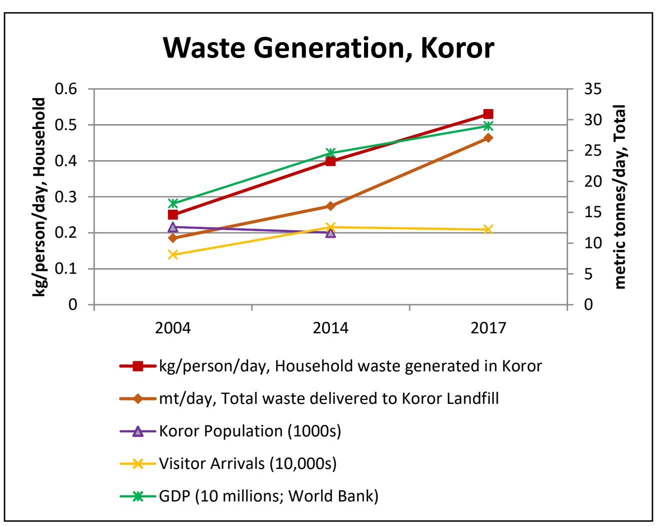
Responses associated with Solid Waste and Recycling

Programs continue to improve, particularly in terms of information, recycling, and collection of special items (e.g. hazardous materials). The total amount of waste recycled or composted increased, but as a proportion of total waste generated, it decreased. Increasing composting would divert significant waste. The Beverage Container Deposit and Redemption Program has successfully diverted most beverage containers from the landfill.

SOE Indicator 100. Solid Waste Generation

Total waste generated has increased drastically, proportionately with GDP, but far more quickly than growth in population or visitorship. 85 to 88% of waste generated ends up landfills (Indicator 103).

	State			Trend	Grade
Data type	*2004*	*2014*[3]	*2017*[4]	*2004-2017*[6]	*2017*[7]
mt/day, Total waste generated, Koror	10.8[1]	16.0	27.1	Increased	Fair
mt/day, Total waste generated, Koror and Babeldaob			28.1[5]		
mt/year, Total waste generated, Koror	3,931[1]	5,840	9,873	Increased	Fair
kg/person/day, Household waste generated, Koror	0.25[2]	0.40	0.53	Increased	Fair



[1] UNCRD (no date)
[2] ADB (2014)
[3] AMITA (2014)
[4] BPW (2017). Draft National Solid Waste Management Strategy 2017-2026. Uses J-PRISM II (June 10-15, 2017). Strategy provides total for Koror and Babeldaob; Koror portion calculated given Urban/Rural percentages provided: 78.7 urban/21.3% rural.
[5] From Figure 3-8 in BPW (2017)
[6] *Notes on Trend:* The first line in Principle 1 in the Draft National Solid Waste Management Strategy is "the preference shall be to reduce the generation of waste and pollutants." Total waste generated has increased, out of proportion with Koror Population growth and Visitor Arrivals.
[7] *Basis for Grade:* Follows 2017 SOE. Palau has lower per capita generation rate than other Pacific islands (0.66 kg/person/day; SPREP 2012) and other tourist destination islands (0.65 kg/person/day; World Bank 2012).

Figure I100. Total waste generated nationally and by household, compared to population, visitor arrivals, and GDP. Calculated from data in BPW (2017), 2015 Census, and World Bank (2019).

SOE Indicator 101. Waste Composition

According to the Draft National Solid Waste Management Strategy 2017-2026 (BPW 2017), household waste is dominated by compostable waste (vegetable/putrescible/kitchen): 44% in Koror and 41% in Babeldaob (Figure I101). Around 30% of Koror's waste is recyclable (paper, plastic, metal, glass, and green waste). Beverage containers are no longer found in household waste in Koror. In Koror, low yard waste (2%) reflects successful diversion of green waste from the landfill.

In Babeldaob, 42% of generated waste is recyclable. A greater percentage of green waste (14%) is found in Babeldaob's waste stream and a small percentage of beverage containers (1%) is still mixed in with regular household waste. These can be attributed to the absence of a green waste collection program on Babeldaob and less proximity to the National Redemption center (BPW 2017).

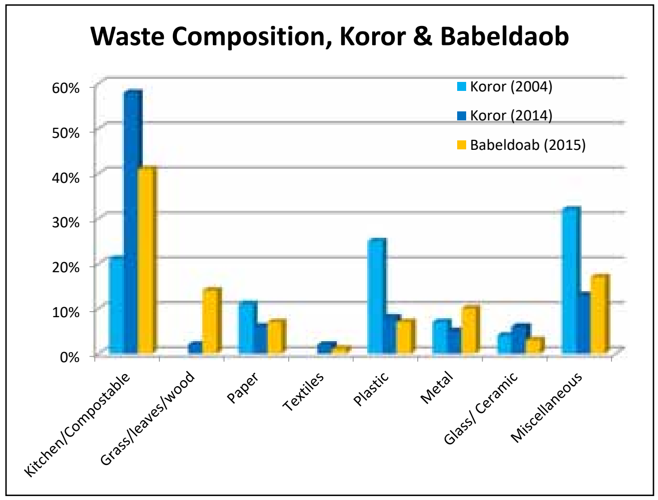


Figure I101. Waste composition. Graphed from data in BPW (2017).

SOE Indicator 102. Waste Source and Collection, Koror

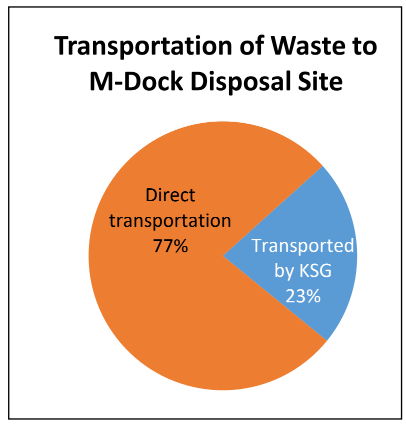
SDG 11.6.1

State Governments are responsible for collection of solid waste. Koror's investment allows for 100% coverage of residential areas, with once-per-week collection, accounting for 23% of wastes brought to the M-Dock Disposal Site (Figure I102a). Collection in Koror's 42 segregation facilities in 7 out of 12 hamlets is done daily, including weekends. These segregation facilities were established in 2007 with bins set up to separately collect paper, plastics, aluminum cans, glass, green waste, and kitchen waste. The system was simplified in 2012 to mixed recyclables and residual wastes. Collection of green waste is upon request (BPW 2017). Figure I102b indicates the originating source of waste to M-Dock (BPW 2017).

In 2017, because of the large volume of food waste in Palau's waste stream (I101), about 40 participating households were provided with composting bins and wood chips by Koror State to facilitate composting of food wastes. These are collected weekly. A pilot project was also collecting food waste from one hotel on request. Free compost was available as an incentive for participation. Food waste from most schools and hotels go to piggery farms (BPW 2017).

As of 2017 there was a special collection of all types of plastics weekly from 45 participating households and 25 participating businesses (mostly auto shops generating big plastic scraps like bumpers). Commercial wastes are collected and disposed by either private companies or by the business owners themselves.

Work on a new National Landfill in Aimeliik began in 2017. Waste from all states will be aggregated and the collection regime will change.



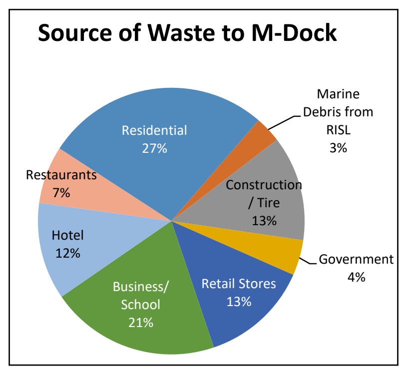


Figure I102a (right top). Percent of waste directly transported to M-Dock, or collected as part of Koror's collection program. Graphed from data in BPW (2017).
Figure I102b (right bottom). Source of waste brought to M-Dock. Graphed from data in BPW (2017).

SOE Indicator 103. Total Diversion/ Recycling Rate

SDG 12.5.1

The National Recycling rate appears to be stable at around 12%. Etibek (2017) estimated that the recycling rate from 2013-2016 was at least 12%. According to J-PRISM II measurements from 2017 in BPW (2017), the national recycling rate (based on disposal at M-Dock) was 11.7%. Etibek (2017) estimated that 51% of residential waste was recycled; however, residential waste accounts for only a small percentage of total waste generated (Indicators 100 and 102). The Palau NBSAP 2015-2025 established a national goal to recycle 65% of Palau's waste. The new National Landfill in Aimeliik will likely change the recycling and collection regime.

	State	Trend[3]	Grade
	2017	*2014-2017*	*2017*
Percent of waste recycled, Koror and Babeldaob	11.7%[1]	Stable (want increase)[3]	Poor (18% of way to goal)[3]
Total waste recycled, Koror and Babeldaob	3.99[1] mt/day		
Percent of Residential waste recycled or diverted	~51%[2]	Stable[3]	Good[4]

[1] BPW (2017), from flowchart (Figure 3-8).
[2] 2017 SOE.
[3] NBSAP goal is recycling 65% of national waste. To meet this, the recycling rate must increase rather than remain stable.
[4] 78% of way to NBSAP goal.

SDG 12.5.1

SOE Indicator 104. Composting amount and rate

Approximately 2% of total waste generated in Koror and Babeldaob is composted (BPW 2017), an average of 0.48 mt/day. This is approximately 8-10% of residential waste. The rate appears to be steady.

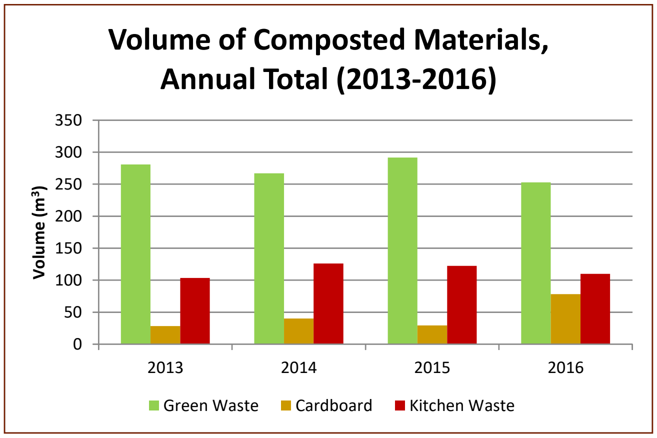


Figure I104. Total composted. Graphed from data in BPW (2017).

	State		Grade
	2009-16	*2013-16*[3]	*2016*
Amount Composted (mt/yr)	~164[1]	~175[2]	Increased
Composting rate (% of residential waste generated)	10%[1]	~8%	Poor
Composting rate (% of total waste generated)		2%	

[1] Calculated from Etibek (2017). Original was presented as total from 2009-2016 (1,153 tons). Composting rate for household waste is provided in report, compared to AMITA (2014).

[2] Calculated from BPW (2017). Original was presented in daily form from 2013-2016 (0.48 mt/day) and as a total yearly percent. Composting rate is calculated as percentage of daily household generation rate (0.48/6.1 mt/day), from J-PRISM II, 2017.

[3] BPW (2017).

[4] *Basis for Grade:* Subjective. Compostables make up the majority of waste generated in Koror (58%) and Babeldaob (41%); thus the amount being composted is very low.

SDG 12.5.1

SOE Indicator 105. Beverage Container and Plastic Recycling

Palau's attempt to recycle plastic (non-beverage) into oil is still in the experimental phase. The facility was repaired after a fire and back in operation in October 2017. Plastic recycling was around 0.10 mt/day; approximately 2% of total waste.

On average (2013-2016), nearly 9 million beverage containers (aluminum and steel cans, plastic, and glass) are redeemed for recycling annually. This diverts 5% of total waste (39% of residential waste) from M-Dock. Since the redemption program began in 2011, 87.3% of containers (less than 32 oz) have been redeemed and then recycled. However, the redemption rate decreased from its start (BPW 2017; Figure I105), indicating a need for more outreach and awareness. Additional data on type of container imported would improve such outreach (DSWM 2017).

2017	State	Grade
Redemption rate, Beverage Containers	87%	Good
Plastic Recycling rate, Total	2%	Poor

[1] DSWM (2017), Beverage Container Recycling Program Annual Report.

[2] *Basis for Grade:* Expected is 80% (DSWM 2017).

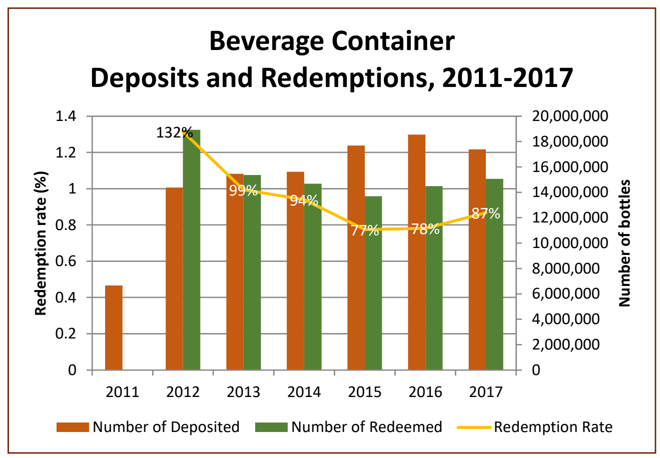


Figure I105. Beverage container recycling. Data from DSWM (2017).

Addressing Pressures, Risks, and Gaps reported in the 2017 SOE

Solid waste management is expected to improve nationwide when the new National Landfill is operational.

Information on waste and recycling improved. Monitoring was undertaken around the M-dock Landfill at regular intervals through the Division of Solid Waste Management, Bureau of Public Works (DSWM-BPW) and Koror State Government (KSG), after a monitoring plan was developed (BPW 2017).

The total amount of waste composted increased, partially through continuous promotion of the composting program in the community, as well as innovative pilots.

DSWM-BPW established a drop off station for hazardous waste (Mottainai Yard).

Increasing waste generation associated with GDP growth is outpacing the capacity of DSWM-BPW, KSG, and the current disposal site at M-Dock.

There is still no overarching Solid Waste Act, but rather an amalgamation of laws (e.g. Environment Quality Protection Act and EQPB Regulations, Recycling Law, Littering Law, Plastic Bag Use Reduction Act). There are still gaps in the disposal of medical waste and types of hazardous wastes.

Agriculture

The information for this section was kindly provided by Palau Automated Land and Resource Information System (PALARIS), or was gleaned from publicly available reports.

State of Agriculture

Agricultural production and participation has increased. All farms in Palau were mapped in 2016, providing an excellent baseline of spatial information. However, there is inadequate tracking of actual production, and growth is too slow to meet demand and targets. The Palau Policy to Strengthen Resilience in Agriculture and Aquaculture ("Food Policy"; Kitalong et al. 2015) sets the goal that local production of food meets 50% of needs by 2020.

Responses for Agriculture

Facilities to serve the agricultural sector have expanded, including opening of the National Slaughterhouse, identification of and support for Best Practices, expansion of agroforestry through nursery trees, and control and removal of IAS (including vines and fruit flies).

SOE Indicator 106. Agricultural Production and Consumption

Agricultural production likely increased, although this information comes from indirect indicators. Total imported value of animal and plant products was steady or slightly decreased between 2013 and 2017 after steadily increasing after 2007. Considering that GDP and generation of waste increased (Indicator 100, Figure I100), as well as the consumer price index for food, this decline of food import value may mean increased consumption of local food products (Figure I106a).

In 2016 PALARIS completed mapping of all farms (PALARIS 2017; see maps next page). The total amount of agricultural land (upland, taro, agroforest) was 543 hectares (5.43 km^2). This is a significant increase from previous estimates of 306 hectares (51 hectares upland (FAO 2014) and 255 hectares taro (Del Rosario et al. 2015); Figure I106b). In 2012 there were 16 commercial farms (FAO 2014); in 2016 there were 19 farms producing exclusively for commercial markets (PALARIS 2017).

The National Slaughterhouse opened in early 2018 (Figure I106c).

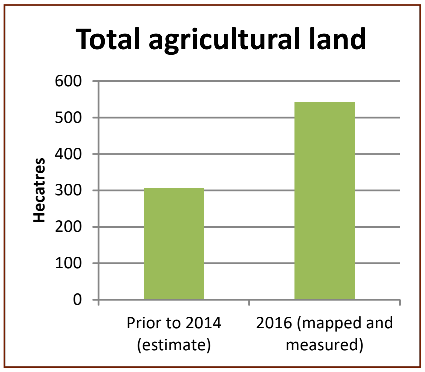


Figure I106b. Total agricultural land. Data from 2017 SOE and PALARIS (2017).

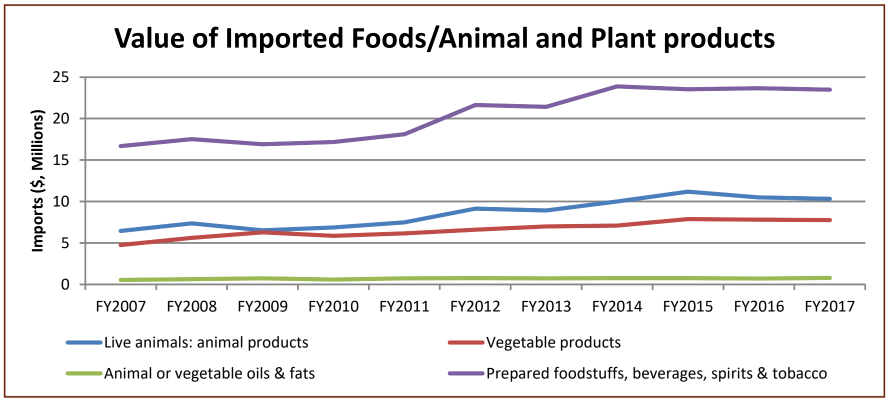


Figure I106a. Imports, FY2007-FY2017 (CIF Value, $US millions). Data on Merchandise Trade from BBP (2019).

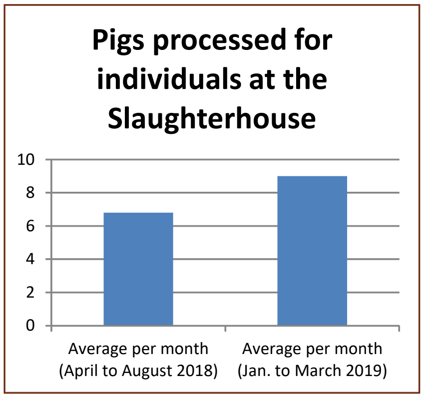


Figure I106c. Average number of pigs processed. Calculated from data in the MNRET newsletters (August 2018 and March 2019).

SDG 5.a.1

SOE Indicator 107. Participation in the Agriculture Sector

The number of participants in agriculture increased. The number of students enrolled in and graduating from agricultural science at the Palau Community College (PCC), plus teaching staff, all increased between 2013 and 2018 (Figure I107a; BBP 2017).

Employment in Agriculture/Forestry (census data is combined) increased both in terms of numbers and percent of the workforce (Figure I107b; BBP 2017). Participation is dominated by men (Table 1); in 2015 31% of total agricultural workers were female (across all types of farming, including taro and upland; and part- and full-time). Women generally have ownership or rights to their agricultural land. 63% of agricultural workers in 2015 were foreign-born/ not Palauan, and mostly male. Foreign-born agricultural workers generally do not have ownership rights.

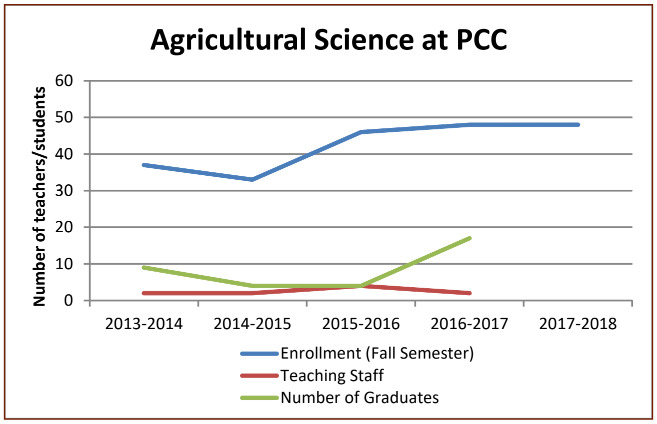


Figure I107a. Enrollment, staff, and graduates in Agricultural Science at PCC. Data from BBP (2017).

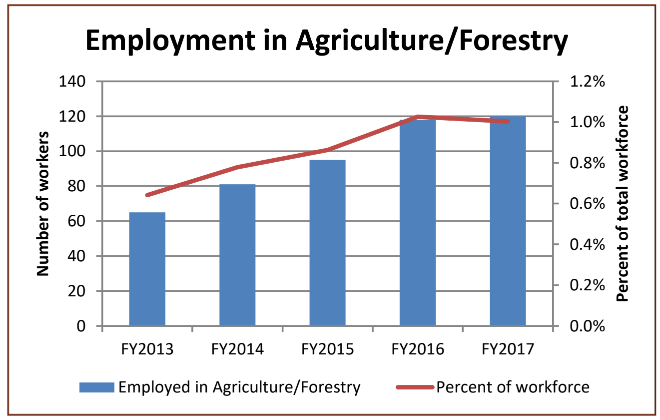
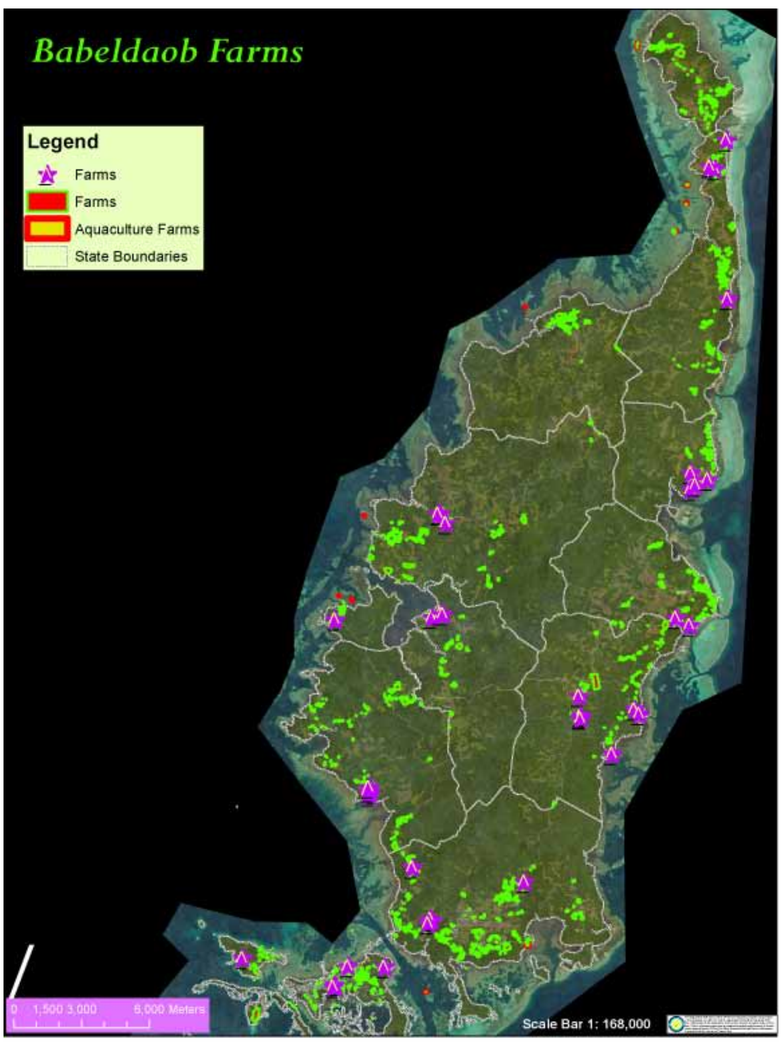
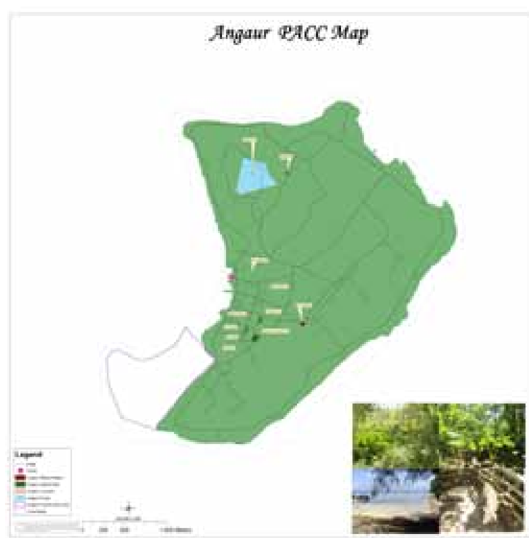


Figure I107b. Employment in Agriculture/Forestry. Data from BBP (2017)





Indicator 106 maps. Example of farm maps: Babeldaob, Koror, and Angaur.

Table 1. Summary Upland Agriculture Sector and Participants

Description	*Total*	*Source*
Total number of mapped upland farms	481	1
Number of those farms producing **exclusively for the market**	19 / 4%	1
Number farms producing for **both** market and subsistence	173 / 36%	1
Number and percent producing **exclusively for subsistence**	302 / 60%	1
Number of upland farms with some wetland or semi-wetland	71 / 15%	1
Total number of farms on Babeldaob	331 / 69%	1
Total number of farms on Koror	116 / 24%	1
Total number of farms on outlying islands	34 / 7%	1
Percent urban farms (116 Koror + 82 Airai) compared to Rural farms (249 rural Babeldaob + 34 outlying island)	41% urban / 59% rural Farms producing any for Market are 50% urban and 50% rural.	1
Locations of highest valued farms ($5000+)	17 farms: 100% Babeldaob; Airai = 10 farms; Aimeliik = 4 farms; Ngaremlengui, Ngatpang, and Ngchesar = 1 farm each. 59% of the highest valued farms are in Airai (defined urban)	1
Average annual production value from market-only farms	$7,300/yr/farm	1
Average annual production value from market/consumption farms	$3,200/yr/farm	1
Number of households operating any land for agriculture purposes	1179 / 25% of 4713 households	2
Average size of household agricultural land (including taro)	1200 square meters/household with land 50% of households owned more than one parcel of land; average size of individual parcels is estimated at 530 m^2.	2
Number of households reporting having a kitchen garden	593 / 13% of total households	3
Number of Full-time Agricultural Workers (includes individuals working in wetland taro)	486 / 29% female; 71% male This is an 8% increase from the number of full-time agricultural workers in the 2005 Census.	2
Number of Part-time Agricultural Workers (includes individuals working in wetland taro)	616 / 33% female; 67% male	2
Individuals reporting income from crops and average income	2,109 individuals (over 15 years old) / $904/person	22
Number of farmers identified as "Organic Farmers"	100[4] PALARIS Farm Survey: 70% of market-only farms use pesticides; 30% of market/consumption farms use pesticides.[1]	4, 1
Origin of agricultural workers	178 Palauan / 307 Foreigner 37% Palauan / 63% Foreigner[2] PALARIS Farm Survey: 12 out of 19 commercial farms hired Farm hands: 51 farm hands, mostly foreign males.[1]	2
Estimated value of fruit and vegetable production (excluding taro)	$3.5 million in 2014	5
Alternative estimated total value of fruit and vegetable production (considering informal sector)	$7 million	6
Estimated total value of betel nut and pepper leaf production	$15 million/yr	7
Number of individuals earning income from handicraft or home processed food production from agricultural products (including taro)	91/ 66% female / 33% male 44% urban / 56% rural	2,3
Estimated value from added-value processing of agricultural products	$1,700 / household	3
Extent of Irrigation	91 parcels out of 1638 permanent crop parcels / 6% 47% of irrigated lands are in Koror and 18% in Airai.	2

[1] PALARIS (2017). Farm Survey.
[2] 2015 Census.
[3] 2014 HIES
[4] ADB (2017)
[5] ROP Economic Review (PITI 2016)
[6] McGregor et al. (2012)
[7] FAO (2014)

Addressing Pressures, Risks, and Gaps reported in the 2017 SOE

There is still inadequate monitoring of production, local use, and local demand, including inputs, outputs, and losses.

Pressures from climate change (see section on Forests) remain high and only some are being mitigated through Best Practices. Biosecurity is slowly improving. The sector is in a difficult situation whereby it needs labor, but the most ready source of labor is foreign. There has not been adequate attention paid to the foreign/local element (e.g. human rights, perceptions, and attitudes).

Energy Sector & Transportation

Photo courtesy of Palau Energy Office

The information for this section was gleaned from publicly available reports, with some assistance from the National Development Bank of Palau (NDBP).

Addressing issues in the 2017 SOE

Growth in renewable energy and efficiency remains slow. Risks associated with car imports are still unmitigated (e.g. through improved regulations and restrictions on imports).

State of Energy

Renewable energy and Energy efficiency both increased, but at a pace that is inadequate to meet goals. Total energy consumption increased drastically, reducing the proportion of renewable energy produced and consumed. Car imports appeared to be decreasing.

SOE Indicator 108. Total Energy/Electricity Consumption

Energy consumption continues to increase. Consumption of electricity held steady for government and PPUC (ROP/Comp Units) between FY2012-2017 and increased for commercial and residential units (Figure I108a). Fuel consumption in gallons increased (Figure I108b).

	State[1]	Trend[2]
Fuel consumption	Total: Increasing	Increased
Electricity consumption	Total: Increasing	Increased

[1] See figures. [2] Palau is moving away from its stated goals.

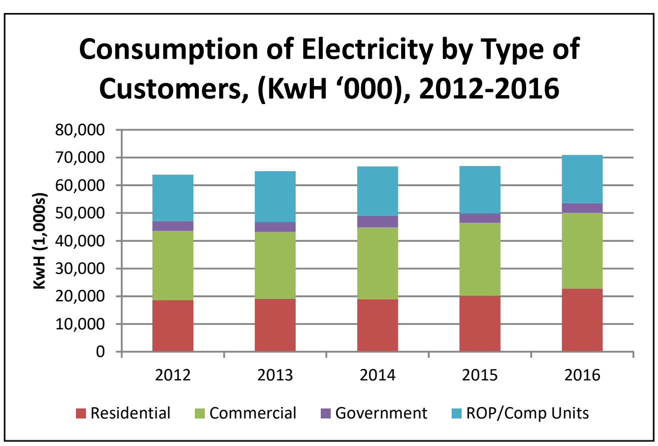


Figure I108a. Consumption of electricity by customer. Graphed using Utility Statistic data (BBP 2019b)

Palau's stated goals (in the both the Palau Energy Policy and the Intended Nationally Determined Contribution (INDC) to the UN Framework Convention on Climate Change (UNFCCC)) is to reduce diesel consumption (from 19.8 to 14.7 million liters/year), and thus reduce CO_2 emissions. The target for CO_2 is to reduce emissions from 53,000 to 39,200 tons/year, from a mixture of reductions, renewables, and efficiencies. At current rates, Palau is moving away from its goals.

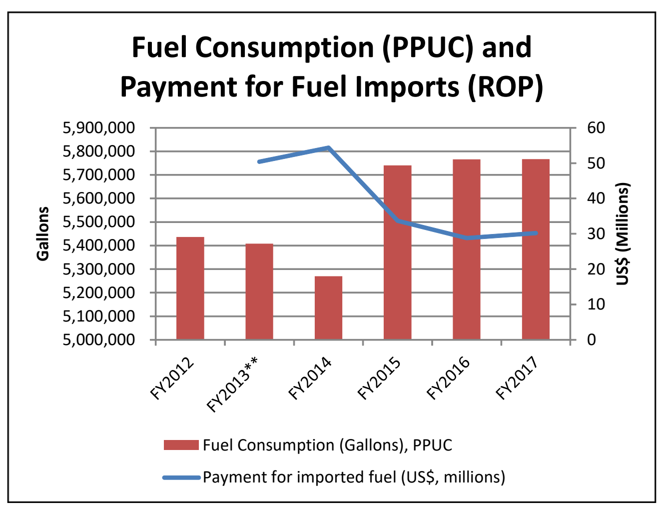


Figure I108b. Fuel comsumption in gallons. Graphed from PPUC (2017). Fuel import information from Balance of Payment statistics (BBP 2019c).

SDG 7.1.2
SDG 7.2.1

SOE Indicator 109. Renewable Energy

8% of Palau's energy came from renewable sources (Palau Energy Office 2018). Share has been increasing steadily, but at its rate (increasing share by 1-3% per year), Palau will not meet its Palau Energy Policy Target by 2020 or its UNFCCC target by 2025. Solar usage in proportion to the total kWh consumption increased from 1% in 2016 to 2% in 2017 (PPUC 2017).

	State	Trend	Grade
Solar Energy Production	• 2015: 1.3 MW[1] • 2018: 3.2 MW[2]	Increased	Poor[6] (INDC)
Renewable Share (of total energy production)	• 2011: 0.3%[3] • 2015: 3.2%[1] • Feb 2017: 5%[4] • Dec 2018: 8%[2]	Increased	Fair (EP)[7] Poor (INDC)
Solar electricity consumption	Increase by all user types[5]	Increased	Baseline

[1] Palau Energy Factsheet (NREL 2016).
[2] Provided by Palau Energy Office, December 2018.
[3] Energy Snapshot, Energy Transition Initiative (NREL 2015).
[4] Provided by Palau Energy Office, February 2017.
[5] PPUC (2017).
[6] When compared to Palau's 2025 INDC (Intended Nationally Determined Contribution/UNFCCC). The INDC target is 38.2 MW, or 45% of production. Palau is 18% of the way to its INDC target.
[7] When compared to the Palau Energy Policy Goal of 20% by 2020. Palau is 40% of the way to its Energy Policy Goal.

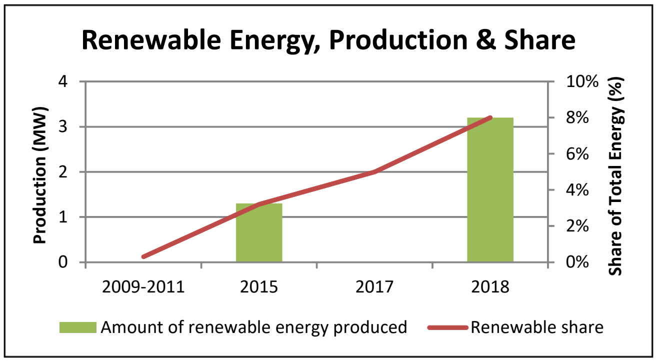


Figure I109a. Renewable energy production and share. See table.

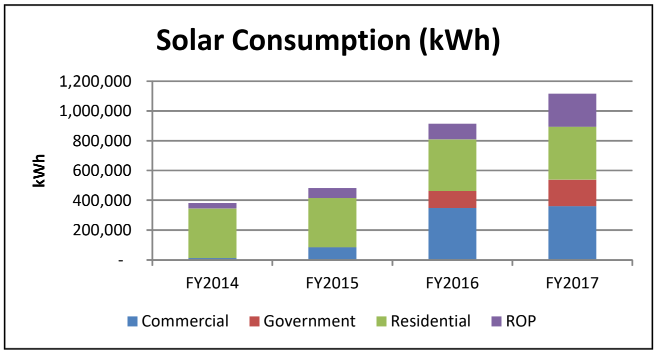


Figure I109b. Solar electricity consumption. Data from PPUC (2017).

SOE Indicator 110. Energy Efficiency

Efficiency increased. PPUC continues efforts towards fuel efficiency and reduction of energy losses by upgrading infrastructure and equipment. Fuel efficiency has been increasing since 2011 and losses have been decreasing since 2014 (Figure I110a; PPUC 2017). NDBP offers a subsidy program to support energy efficient homes (or upgrades). Participation varies based on both funds availability and homeowner participation (Figure I110b). Residential and government efficiency savings, representing a savings of 4% of total energy produced, were from one-time projects (e.g. CFL Campaign, in 2017 SOE).

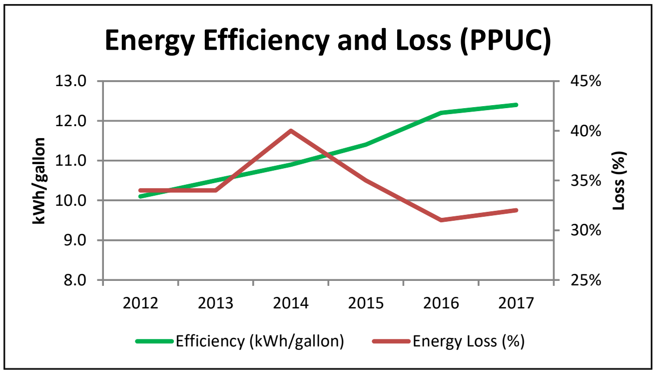


Figure I110a. Energy efficiency and losses. Data from PPUC (2017).

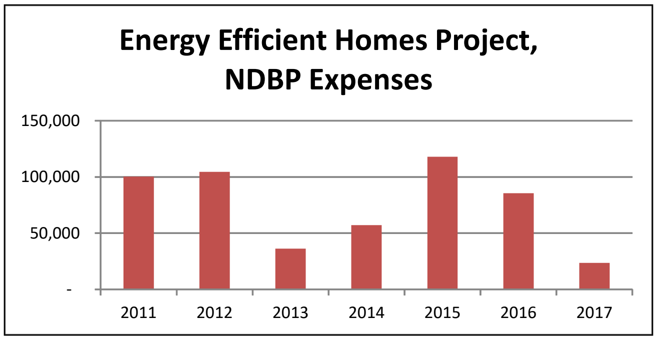


Figure I110b. NDBP offers a subsidy for energy efficient homes. Graphed from NDBP Audits (2011-2017).

SOE Indicator 111 Vehicles/Imports

It appears that vehicle imports may be slowing, after a peak in 2011, as suggested by declining car imports (through 2016; Division of Customs 2017) and declining total value of vehicle imports (BBP 2017). However, the total number of registered cars in Palau remains high (Figure I111).

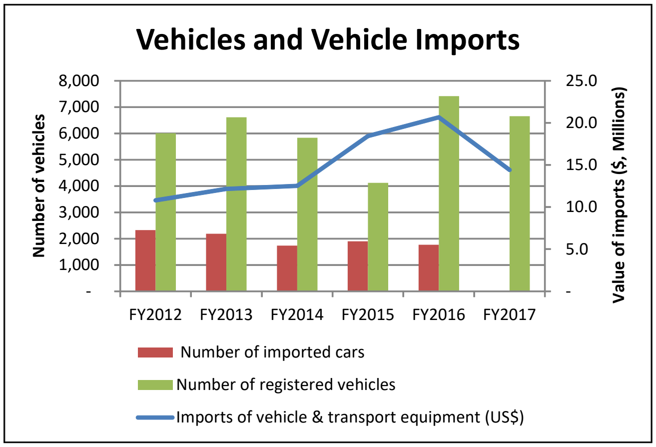


Figure I111. Number of cars imported graphed from Division of Customs 2017). Number of registered cars and value of imported vehicles graphed from BBP (2017).

Environmental Health

Photo by A. Gupta

Dengue Outbreak

In December 2018 the Ministry of Health (MOH) activated its Emergency Response Team to address an outbreak of Dengue Fever. Between December 2018 and April 2019 the Division of Environmental Health has been active with dengue prevention through vector control and strengthening mosquito control. Between December 2018 and April 7, 2019 there were 150 lab-confirmed cases of Dengue (MOH April 9, 2019 Dengue Report; Figure, right).

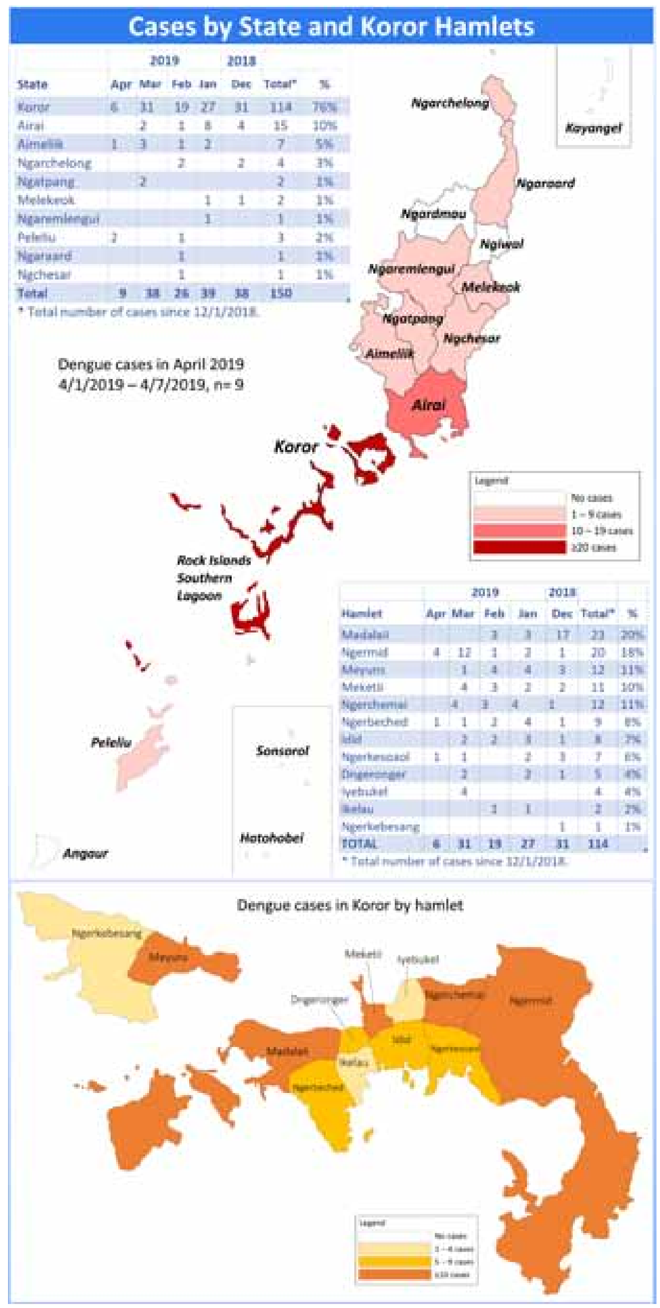
An outbreak of Dengue Fever occurred between October 2016 an June 2017, with a total of 329 cases (MOH 2017). There was a small increase in Dengue Fever cases in 2011 (120 cases) although the number did not reach outbreak status. The last outbreak was in 2008, with 202 cases (Appanaitis 2014).

Healthy Diets and Lifestyles

The percent of adults who ate five daily servings of fruit and vegetables increased slightly (8% in 2015; 9.9% in 2017). 20% of adults reported eating less than one serving of fruits or vegetables daily. 49% of adults were characterized as having a Low Level of Physical Activity (MOH 2017b).

In 2016, 29% of children aged 5-11 were overweight or obese (19% obese). 17% of children had Light or Inactive physical activity (MOH 2017).

Health is a consideration in landscape and land use planning efforts and agriculture.



Figure, right. A panel from the MOH weekly Dengue report. #18, accessing April 15, 2019. http://www.palauhealth.org/MOHpages/MOHDengueSituation1.aspx

Awareness & Capacity

Photo courtesy of BWA/R2R

The information for this section was kindly provided by the Palau Conservation Society (PCS), or was gleaned from publicly available reports.

State of Awareness and Capacity

Public awareness of environmental and conservation issues remains high, although may have decreased. The sector has shifted towards targeted outreach to key stakeholders who directly influence resource use or management. Additionally, the sector is now investing in improving public participation in environmental activities and decision-making. Indicators for public participation are relatively low, or set here as baseline information. The growth of PAN and the introduction of new initiatives (such as the Sustainable Tourism Framework and biennial National Environment Symposium) has brought many new people into the environment sector. Thus most indicators here are presented as baseline.

Responses for Awareness and Capacity

The Environment Sector remains very active and is increasing its own capacity and inclusivity, as well as that of stakeholders. There are many targeted and national opportunities to participate in conservation or benefit from capacity building. The sector also rapidly adopts and transfers new skills to key stakeholders (e.g. Results Based Management).

SOE Indicator 112. Public Awareness

The environmental sector continued to invest in public outreach, and maintains high levels of awareness in the public on issues of conservation. The percentage of community members aware of certain initiatives (PAN, Bul, and Conservation Areas) decreased in the period of the 2017 SOE and this 2019 SOE. The two reports used socioeconomic surveys from different states. This may be due to a shift to more targeted stakeholder-driven outreach rather than public outreach; however the conservation community should keep an eye on this indicator.

Community awareness of:	State[1]	Change[2]	Grade[4]
Aware of PAN	78%	Decreased (92%)	Good
Aware of Bul	81%	Decreased (86%)	Good
Aware of their State's Conservation Area(s)	87%	Decreased (92%)	Good
Aware (at all, even if low) of regulations pertaining to their State's Conservation Area(s)	55%	Decreased (70%)	Fair
Aware of the Micronesia Challenge	46%	Increased (43%)	Fair
Highest on-island population using the Internet to access Palau Wave Radio during conservation-related shows	6%[3]		Baseline
Average number of times PCS Talk Show Videos are viewed (online) on 87.9 Eco-Paradise	700[3]		Baseline
Percent of 4th and 5th graders participating in field activities as part of the Ridge to Reef Program (2016)	86%[3]		Good

[1] Socioeconomic surveys from 2017 to 2019 for Angaur, Airai, Melekeok, Ngatpang, and Koror:
1. Marino et al. (2019-Koror)
2. Marino and Jonathan (2018-Angaur)
3. Marino and Jonathan (2018-Melekeok)
4. Marino et al. (2017-Ngatpang)
5. Marino et al. (2017-Airai)

[2] Compared to values in the 2017 SOE. 2017 averaged 5 Socioeconomic surveys from Peleliu, Ngiwal, Kayangel, Ngchesar, and Ngaraard.

[3] Data from PCS (2019b).

[4] *Basis for Grade*: Subjective. >75% is defined as Good. The 2015-2025 NBSAP calls for an increase of 30% (of public awareness of biodiversity issues).

SOE Indicator 113. Public Participation in Environment

The Palau NBSAP includes a goal of increasing public participation in environmental decision making process. Together with awareness, public participation provides evidence for public resilience and self-reliance.

Community who have:	State	Grade
I or someone in my household have participated in some form of environmental outreach	47%[1] (Decreased - 69%)	Fair[7]
I or someone in my household participate in **most/all** of the activities related to the Conservation Area(s) in my State	11%[1]	Good[8]
Average number of participants participating in hearings for proposed development projects	43[2]	Baseline
Number and Percent of Dive Shops participating in Green Fins Initiative (e.g. sustainable industry guidelines)	9[3] (47% of dive shops; 29% of tour operators)	Baseline
Ratio of Number of participants in the 2018 National Dialogue on environment issues in Palau to Number of employees in the NGO and non-profit sector	89:239[4] (1:3)	Baseline
Average number of participants in State Protected Area/Conservation Planning Teams	13[5]	Baseline
Ratio of Number of members of the Palau Conservation Society to Number of adults/workforce (16+) in Palau	543:13,823[6] (1:25)	Baseline

[1] Socioeconomic surveys from 2017 to 2019 for Angaur, Airai, Melekeok, Ngatpang, and Koror. See Indicator 112 for references.
[2] At 2018 Public Hearings: Jennifer Renguul & Charley Kenty Project (Koror) - 25 participants; Ngarchelong Sandmining Project - 69; Funeral Home and Chapel (Airai) - 35. Data from PCS (2019b).
[3] Number of participating Green Fins members from PCS (2019b). Total number of Dive Shops in the PNCC 2018 phone book is 19; total number of Tour Operators is 31.
[4] Number of National Dialogue participants from PCS (2019b). Number of NGO/Non-profit from BBP (2017); assumed to be same for 2018. Not all participants in the National Dialogue are employed by the NGO/non-profit sector.
[5] Active in 2018: Ngaraard - 16; Ngardmau - 11; Airai - 12
[6] Number of members from PCS (2019b). Number in labor force from 2015 Census; assumed same for 2018.
[7] *Basis for Grade:* Subjective. Good >75%; Fair=30-75%; Poor <30%.
[8] *Basis for Grade:* Subjective. Good is more than 10% of community active in all or most activities.

SOE Indicator 114. Capacity Building

The growth of PAN and adoption of the Sustainable Tourism Framework are two examples of how the environment sector has truly become more community-based, with hundreds of new participants. Building the capacity of these new environmental sector employees, volunteers, and community members introduced new challenges that are only now being addressed. A significant push in the last two years has been to build management and planning skills within PAN and communities, with an emphasis on Results Based Management (RBM).

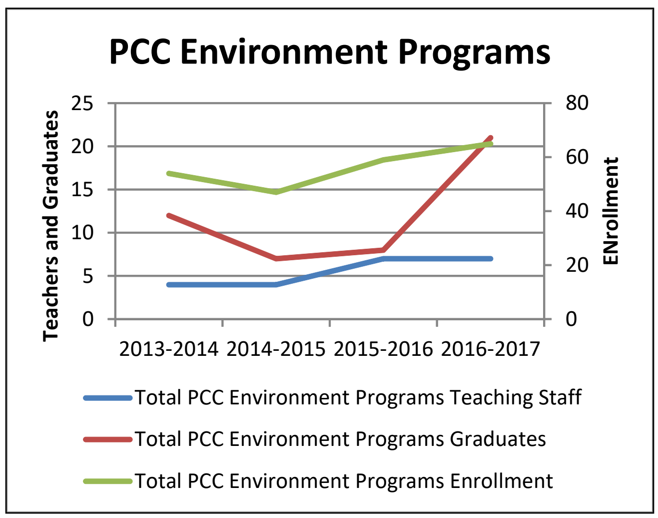


Figure I114 (right). Trends in PCC teaching, graduates, and enrollment. Environment Programs compiled from Agricultural Science (AgSci), Environmental/Marine Science (Env/MarSci), and STEM. Data from BBP (2017).

	State	Grade
Percent of PAN Officers or PAN Staff who took part in field training	32%[1]	Fair[6]
Percent of PAN Officers who participated in Results Based Management (RBM) training	27%[2]	Baseline
Ratio of Number of participants in dialogues/trainings on RBM to Number of employees in the NGO and non-profit sector	59:239[3] (1:4)	Baseline
Percent of K-12 teachers participating in trainings on biodiversity or sustainable development	44%[4]	Baseline
Teaching Staff, Graduates, and Enrollment at PCC in Environment Programs (Agricultural Science, Environmental/Marine Science, or STEM). See Figure I114.	2013-2014: 70[5] 2016-2017: 93	Increasing

[1] Forest monitoring and Surveillance training (PCS 2019b). 94 Employees paid for by PAN Fund (PAN Fund 2017).
[2] 25 participants in training (PCS 2019b).
[3] Number of RBM participants from PCS (2019b). Number of NGO/Non-profit from BBP (2017); assumed to be same for 2018.
[4] Number of participants from PCS (2019b). Number in teachers from MOE (2016 - Education Statistical Yearbook); assumed to be the same for 2019.
[5] All PCC numbers from BBP (2017).
6 *Basis for Grade:* Subjective. Good is >75%; Fair is 30-75%; Poor is <30%.

Gender & Social Inclusion

Photo by A. Gupta

This section is written in loving memory of Dr. Caleb Otto,
a passionate champion for human rights
and a tireless advocate for the health of humans and the environment

Palau is different from much of the developing world in that women have a strong voice and role in decision making. However, roles are rapidly changing for every gender, age, and socioeconomic bracket. Palau's Gender Division has adopted an approach of overall inclusivity, focused on both gender and multiple vulnerable populations. Whether a person is vulnerable varies highly with the situation. Palau's Gender Mainstreaming Policy states that a "Gender and Socially Inclusive and Balanced lens" be applied to every project.

The Environment Sector/Conservation Community has begun to incorporate Gender and Social Inclusion as part of implementing large, GEF-funded National Projects. Projects include targets for gender and social inclusion at the community implementation level and an increase in capacity for resource managers to mainstream inclusion. Baselines have been determined; Table 1 shows the breakdown for male/female participation in State Planning Teams (e.g. as relates to land use planning or PAN Site planning). Targets include increasing representation by genders and multiple social groups. Mainstreaming of gender and social inclusion will also follow a newly established Project Management Manual Handbook.

The Conservation Community assessed its own ability to implement Gender and Social Mainstreaming. In 2017, most individuals working in the Conservation Community did not feel well-prepared to implement projects with a gender and socially-inclusive lens. Table 2 shows the results of the self-assessment on existing gender and socially inclusive mainstreaming and/or capacity to do so.

A baseline analysis was conducted in May 2017 as part of the preparation phase for the GEF6 National Project, and in May 2018 in preparation for the mid-term review of the GEF5 National Project. One of the key findings was that the outcomes of national attempts to incorporate Land Use Planning and PAN/Protected Areas Planning could have negative, unintended consequences on genders and social groups without

Table 1. Baseline information on Gender differences in State Planning Teams and Conservation Activities[1]

Indicator (N=9 States surveyed)	*% Men*	*% Women*
Representation on planning teams	77%	23%
Representation working in State Office	69%	31%
Representation of people working in State's Conservation/PAN/Environment Office	78%	22%
Community members who participated in biodiversity projects last year	43%	57%
Community members who participated in capacity building activities last year	54%	46%
Level of Biosecurity/IAS awareness (high, medium, low) (N = 6 States surveyed)	low	medium
Level of participation in sustainable tourism by community members (N=6)	medium	Low
Indicator Question (N=9 States surveyed)		*Average Score [2]*
Do men and women have access to State Planning teams?		1.3
Do men and women participate and/or play an active role in Planning Team meetings?		1.7
Who benefits from biodiversity-related training and capacity building programs?		1.2
Who participated in past biodiversity-related projects?		1.7
Who benefitted from past biodiversity-related projects?		1.7

[1] Surveys were conducted in May 2017 as part of planning for the GEF6 National Project.

[2] Scores were assigned as follows:
- 0 Only one gender
- 1 Representation from both genders, but it is not equal
- 2 Equal representation from men and women
- 3 Equal representation from men and women, and they represent different social status levels in society

explicit incorporation of Gender and Socially Inclusive Mainstreaming.

Key findings, Women and Environment

In 2015 males made up 53% of the population and females 47%. Palau is a matriarchal, matrilineal society at an "interesting crossroads between the forces of tradition and modernization" (Otto 2008). Traditionally men and women had distinct roles but were considered each equally important to society. As Palau has modernized gender roles have followed varied trajectories. For instance, more women than men are employed in the government and are better educated (Otto 2008), but women hold fewer positions of power (both elected and traditional; ADB 2017), except in the Judiciary.

Palau performs well on Sustainable Development Goal (SDG) indicators: maternal health is high and both boys and girls have access to education, with more women attaining higher education than men (Kitalong 2013).

Challenges to gender equality are in every sector at every level. Climate Change appears to be disproportionately negatively affecting women (Temengil and Kitalong 2014); sea level rise and intense storms have destroyed or degraded natural habitats that women rely on such as taro patches and seagrass beds.

In assessing Palau's private sector, the Asian Development Bank (ADB 2017) found that women are generally not empowered in the financial sector, which is limiting national development of sustainable enterprises, particularly in the locally-led sustainable tourism industry.

Key findings, Vulnerable Peoples and the Environment

There is a distinct disparity between Urban and Rural residents. In 2015 80% of the population was urban (in Koror and the suburb of Airai). In 2014, 91% of urban households versus 74% of rural households had a member with a wage-paying job. Average income for urban households was $16,670 and for rural households was $13,340 (2014 HIES).

60% of rural households, but only 30% of urban households, relied on marine resources for some or all of their subsistence protein needs (in 2014). Rural households are more likely to have limited access to varied habitats because they own smaller boats with less gear. Urban residents have more flexibility and are able to adapt to change; following typhoons in 2012 and 2013 urban fishers—mostly male—were able to access fishing grounds far from home; whereas rural fishers did not have that same flexibility. This flexibility means that urban fishers were able to catch and sell excess fish to markets by a factor of 4:1 to rural fishers, who utilize their catches to meet subsistence food needs.

In 2015 27% of the population in Palau were foreign workers, who dominate the tourism and agriculture industries. Although many are members of NGOs and civic organizations, they have little decision-making authority.

A key vulnerable population are young men between the ages of 17 and 40, who have the highest rates of un/underemployment in the country. Young men are less likely to advocate for their needs (e.g. in Land Use or Protected Areas planning processes). The European Union-funded Global Climate Change Alliance Project identified young men as one of the most vulnerable populations to Climate Change, and developed specific project activities to attract young men.

Table 2. Self-Assessment on Capacity of the Environment Sector/Conservation Community to mainstream gender and social inclusion[1]

Indicator Question (N=12)	*Average Score*
Are there gender issues related to **men** that need to be addressed in the Environment sector?	3.4
Are there gender issues related to **women** that need to be addressed in the Environment sector?	3.3
Do plans for biodiversity projects include activities that strengthen skills and provide women/girls with equal access to services and training?	2.9
Do plans for biodiversity projects include activities that strengthen skills and provide men/boys with equal access to services and training?	2.7
Implementing agencies are gender-friendly	2.6
Are gender equality goals and objectives included in biodiversity projects or mainstreaming goals?	2.5
Has gender expertise increased within the biodiversity conservation sector?	2.2
Does project planning considers the needs of all vulnerable peoples?	2.9
Implementing agencies consider the needs of all vulnerable peoples (across all levels of society)	2.2
Do biodiversity conservation staff have the necessary knowledge, skills and attitude to carry out their work with gender awareness?	2.0
Is there assigned staff responsibility for gender integration in National environmental offices?	1.9
Do biodiversity conservation office and organizational practices support gender equality?	1.9
Have biodiversity conservation staff been trained in gender awareness and sensitization?	1.8
Are there adequate training and tools on gender planning, analysis and evaluation available?	1.8
Is gender awareness included in job descriptions and/or evaluation criteria within the biodiversity conservation sector?	1.6
Do hires and subcontractors have TORs, job descriptions, or evaluation criteria that include social inclusivity and gender awareness?	1.35
Is there a person or department responsible for gender in the biodiversity conservation sector?	1.4
Do biodiversity projects budget adequate financial resources to support gender integration work?	1.3
Do biodiversity conservation offices and organizations have written policies or goals that affirm a commitment to gender and social equality or inclusion?	1.0
Average Score out of maximum of 5 (per question)	2.1/5

[1] Surveys were conducted in May 2017 as part of planning for the GEF6 National Project, and repeated in March 2018 as part of the GEF5 National Project.

[2] Scores were assigned as follows:
1 Not at all
2 To a LIMITED extent
3 To a MODERATE extent
4 To a GREAT extent
5 To the FULLEST extent

Conclusions & Next Steps

Photo courtesy of BWA/R2R

We should be proud. We have healthy reefs and healthy forests. Our communities have clean water, sanitation, fresh foods, recycling programs, support for clean energy, and dedicated environmental health programs. We have passionate, committed Champions who excite and empower others to preserve and protect Palau and its resources.

The Environment Sector and our Communities collaborate well together, are highly informed, able to embrace change, quick to incorporate new and better methods, and has a track record for fixing problems. All of the pressures facing our environment can be fixed by these strengths.

Tomorrow:

- We must address Nearshore Fisheries, loudly and directly (not through offshore fisheries). Elected leaders must take the lead–as they did with Protected Areas and PAN nearly 20 years ago–and pull the disparate groups and individuals together in a funded Task Force. We must first acknowledge that this problem cannot be solved by fishers, communities, and NGOs alone. It needs direct support from the National Government. Then, we must identify what we don't know (e.g. harvests and harvest limits), and then get that information. Policymakers must be prepared to allocate funding and update laws and regulations on quotas, closures, taxes, and imports; some of these decisions will be hard.
- We must actively apply a gender and socially inclusive lens to everything we do.

Next week:

- As a National Government, we must commit to Land Use Planning. We cannot expect States to do it on their own, with limited help from the environmental sector and grants. We need to take the lead by updating our own National Master Plan. Land Use Planning needs national leadership. We cannot be only reactive to earthmoving permit applications and development.
- We must push harder at the International level for climate mitigation. Climate Change puts pressure on every habitat, natural resource, and sector. To prove we are serious, we need to actively increase renewable energy and energy efficiency.
- We must review our imports, pricing, and tax structures to better value our natural resources and to decrease consumption and solid waste.

Next month:

- We need to actively work to fill in gaps in our Protected Areas Network. PAs work, and we need more channels, back reefs, reef flats, shorebird sites, and forests to be protected. All the systems are in place to make this happen.
- The National Government needs to clearly take leadership on mangroves in order to meet the "No Net Loss" policy goal. Mangroves need to be treated like a national resource, not only State.
- We need to start drafting Species Action Plans for our endangered and threatened species, so that our most critical species are actively managed in the next 2 years.
- We need to make a 2+ year plan to fill in data gaps, across all habitats and sectors.

Maintain:

- We will continue down the path of Sustainable Tourism, Coral Reef conservation, PAN implementation, Recycling and Reuse, Water Treatment, growth in Agriculture, and Outreach.

References

Photo by B. Bintorio

Aeby, G.S., G.J. Williams, E.C. Franklin, J. Kenyon, E.F. Cox, and S. Coles. 2011. Patterns of Coral Disease across the Hawaiian Archipelago: Relating Disease to Environment. PLoS ONE 6(5): e20370. doi:10.1371/journal.pone.0020370.

AMITA Institute for Sustainable Economies Co., Ltd. 2014. Prompt report for waste survey in Palau. PowerPoint Presentation. Provided by Koror State.

Andradi-Brown, D., J. Laverick, I. Bejarano, T. Bridge, P.L. Colin, G. Eyal, R. Jones, S. Kahng, J. Reed, T. Smith, and H. Spalding. 2016. Threats to mesophotic coral ecosystems and management options. Mesophotic coral ecosystems—a lifeboat for coral reefs, pp.67-82.

Anseeuw, P., L.J. Bell, and M.G. Harasewych. 2017. *Bayerotrochus belauensis*, a new species of pleurotomariid from the Palau Islands, western Pacific (Gastropoda: leurotomariidae). NAUTILUS, 131(2), pp.138-146.

Appanaitis, Inger. 2014. National Health Profile 2013. Ministry of Health: Koror, Palau.

Asian Development Bank (ADB). 2018. Concept Paper: Proposed Policy-Based Loan. Republic of Palau: Disaster Resilience Program.

Asian Development Bank (ADB). 2017. Private Sector Assessment for Palau. DOI: http://dx.doi.org/10.22617/RPT178664-2.

Asian Development Bank (ADB). 2014. Solid Waste Management in the Pacific: Palau Country Snapshot. Publication #42665.

Asian Development Bank (ADB). 2011. Food Security and Climate Change in the Pacific. ADB: Manila.

Barange, M. G. Merino, J.L. Blanchard, J. Scholtens, J. Harle, E.H. Allison, J.I. Allen, J. Holt, and S. Jennings. 2014. Impacts of climate change on marine ecosystem production in societies dependent on fisheries. Nature Climate Change 4: 211–216.

Barfield, Miranda, Mochi Li, Shannon Miner, Daniel Patel, Kyla Wilson, and Lina Yang. 2017. Global Analysis of Offshore Mariculture. UCLA Intitute of the Environment and Sustainability.

Barkley, Hannah C., Anne L. Cohen, Daniel C. McCorkle, and Yimnang Golbuu. 2017. Mechanisms and thresholds for pH tolerance in Palau corals. Journal of Experimental Marine Biology and Ecology 489 (2017) 7–14. http://dx.doi.org/10.1016/j.jembe.2017.01.003.

Barr, Rhona, Nina Ullery, Irvin Dwight, and Aaron Bruner. 2016. Palau's sea cucumber fisheries: the economic rationale for sustainable management. Conservation Strategy Fund Technical Series #44.

Bejarano, S.C., P.J. Mumby, and Y. Golbuu. 2014. Changes in the spear fishery of herbivores associated with the closed grouper season in Palau, Micronesia. Animal Conservation, 17: (2014)133-143. The Zoological Society of London.

Bejarano, S.C., Y. Golbuu, T. Sapolu, and P. Mumby. 2013. Ecological risk and the exploitation of herbivorous reef fish across Micronesia. Marine Ecology Progress Series 482:197–215.

Belau National Museum (BNM). 2017. State of Palau's Birds.

Belau National Museum (BNM). 2016. State of Palau's Birds.

Belau National Museum (BNM). 2014. State of Palau's Birds.

Belau National Museum (BNM) and Alan Olsen. 2015. Recent advances in the monitoring of birds as indicators of ecosystem change for the Palau PAN: A briefing from the National Program for Monitoring Forest and Coastal Birds. Unpublished.

Bell, J.D., J.E. Johnson, A.S. Ganachaud, P.C. Gehrke, A.J. Hobday, O. Hoegh-Guldberg, R. Le Borgne, P. Lehodey, J.M. Lough, T. Pickering, M.S. Pratchett, and M. Waycott. 2011. Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change: Summary for Pacific Island Countries and Territories. Secretariat of the Pacific Community (SPC), Noumea, New Caledonia.

Bell, J.D., M. Taylor, M. Amos, and N. Andrew. 2016. Climate change and Pacific Island food systems. CCAFS and CTA. Copenhagen, Denmark and Wageningen, the Netherlands.

Bigue, Marcel and Oswaldo Rosero. 2014. Palau Northern Reef Assessment: Control and Vigilance System Design. WildAid, San Francisco, CA.

BirdLife International. 2019. Country profile: Palau. http://www.birdlife.org/datazone/country/palau. Accessed 4/24/2019.

Birkeland, Charles. 2017. Working with, not against, coral-reef fisheries. Coral Reefs (2017) 36: 1. https://doi.org/10.1007/s00338-016-1535-8.

Bourke, Richard and T. Harwood. 2009. Food and Agriculture in Papua New Guinea. ANU E-Press, The Australian National University, Canberra.

Bright, G.R. and J.A. June. 1981. Freshwater fishes of Palau, Caroline Islands. Micronesica 17(1/2):107-111.

Brooks, Richard. 2018. Filming the Palau Dugong. The rarest of the rare. http://behind-the-scenes.lightningstrikeproductions.co.uk/filming-palau-rare-wildlife-dugong/. Accessed 3/7/2019.

Bureau of Budget and Planning (BBP). 2019. Merchandise Trade, Imports by HS Sections, FY2007-FY2017 (CIF Value, $US millions). https://www.palaugov.pw/executive-branch/ministries/finance/budgetandplanning/merchandise-trade/. Accessed 4/10/2019.

Bureau of Budget and Planning (BBP). 2019b. Utility Statistics. https://www.palaugov.pw/executive-branch/ministries/finance/budgetandplanning/utility-statistics/. Accessed 4/10/2019.

Bureau of Budget and Planning (BBP). 2019c. Balance of Payments Statistics. https://www.palaugov.pw/executive-branch/ministries/finance/budgetandplanning/balance-of-payments/. Accessed 4/10/2019.

Bureau of Budget and Planning (BBP). 2019d. Climate Statistics. https://www.palaugov.pw/executive-branch/ministries/finance/budgetandplanning/climate-statistics/. Accessed 1/28/2019.

Bureau of Budget and Planning (BBP). 2017 Statistical Yearbook. Ministry of Finance, Koror, Palau. http://palaugov.pw/wp-content/uploads/2018/07/2017-Statistical-Yearbook-Final.pdf.

Bureau of Marine Resources (BMR). 2017. Marine Resources Export 2016 Report.

Bureau of Marine Resources (BMR). 2016. Marine Resources Export 2016 Report.

Bureau of Marine Resources (BMR). 2015. Marine Resources Export 2015 Report.

Bureau of Oceanic Fishery Management (BOFM). 2016. Annual Report to the Western and Central Pacific Fisheries Commission (WCPFC). Bali, Indonesia.

Bureau of Oceanic Fishery Management (BOFM). 2015. Annual Report to the Western and Central Pacific Fisheries Commission (WCPFC). Pohnpei, Micronesia.

Bureau of Public Works (BPW). 2017. National Solid Waste Management Strategy: The Roadmap towards a Clean and Safe Palau 2017 to 2026.

Campbell, Marnie L., Chad L. Hewitt, and Joel Miles. 2016. Marine pests in paradise: capacity building, awareness raising and preliminary introduced species port survey results in the Republic of Palau. Management 7.4: 351-363.

Cannon, Phil G., Margie Falanruw, Francis Ruegorong, Richard MacKenzie, Katie Friday, Amy L. Ross-Davis, Sara M. Ashiglar, Ned B. Klopfenstein, Zhangfeng Liu, Mohammed Golabi, and Chancy Thomas Iyekar. 2014. The causes of mangrove death on Yap, Palau, Pohnpei and Kosrae [Chapter II]. In: Cannon, Phil. 2014. Forest pathology in Yap, Palau, Pohnpei, Kosrae, Guam and Saipan, Sept. 2013. Trip Report. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Region 5, Forest Health Protection. p. 13-37.

Carlisle, Keith M. and Rebecca L. Gruby. 2018. Why the path to polycentricity matters: evidence from fisheries governance in Palau. Env Pol Gov. 2018;28:223–235.

CEA. 2016. Palau Fisheries: 2015 Summary. Prepared for The David and Lucile Packard Foundation. .

Census. 2015. Census of Population, Housing and Agriculture. Bureau of Budget and Planning, Ministry of Finance.

Cimino, Megan A., Mark Anderson, Travis Schramek, Sophia Merrifield, and Eric J. Terrill. 2019. Towards a Fishing Pressure Prediction System for a Western Pacific EEZ. Nature: Scientific Reports 9:461. DOI:10.1038/s41598-018-36915-x.

Cimino, Megan A., S. Patris, G. Ucharm, L.J. Bell, and E. Terrill. 2018. Jellyfish distribution and abundance in relation to the physical habitat of Jellyfish Lake, Palau. Journal of Tropical Ecology, 34(1), pp.17-31.

Cole, T.G., M.C. Falanruw, C.D. MacLean, C.D. Whitesell, and A. M. Ambacher. 1987. Vegetation survey of the Republic of Palau. Resource Bulletin PSW-22. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest.

Colin, P.L., 2019. Information and analysis prepared for the 2019 SOE. Unpublished. Coral Reef Research Foundation (CRRF): Koror, Palau.

Colin, P.L. 2009. Marine Environments of Palau. Indo-Pacific Press, Calif. 414 pp.

Colin, P.L., 2018. Ocean warming and the reefs of Palau. Oceanography, 31(2), pp.126-135.

Colin, P.L., 2018b. *Thalassodendron ciliatum* (Cymodoceaceae) in Palau: Occurrence, typhoon impacts and changes over time. Botanica Marina, 61(6), pp.537-546.

Colin, P.L. 2016a. Going to Extremes: ENSO Variation in Water Temperature and Sea Level in Coral Reefs in the 21st Century. Presented at 2016 Palau First National Environmental Symposium. August 23-24, 2016: Koror, Palau.

Colin, P.L. 2016b. Spotlight on the Palau Island group, 31-36 in: Baker, E.K., Puglise, K.A. and Harris, P.T., Mesophotic coral ecosystems–A lifeboat for coral reefs? The United Nations Environment Programme and GRID-Arendal, Nairobi and Arendal, 98 pp.

Colin, P.L. and S. Lindfield. 2019. Palau. in: Puglise, K., Y. Loya, and T. Bridge. Mesophotic Coral Reefs of the World, Springer, Chapter 16.

Collins, Paul, Susan Cordell, Julian Dendy, Christian Giardina, Dino Mesubed, and Amanda Uowolo. 2015. Poster: Landscape Change on Babeldaob Island, Palau. CRRF: Koror, Palau. https://coralreefpalau.org/education/posters/.

Conroy, J.L., D.M. Thompson, K.M. Cobb, D. Noone, S. Rea, and A.N. Legrande. 2017. Spatiotemporal variability in the δ18O□ salinity relationship of seawater across the tropical Pacific Ocean. Paleoceanography, 32(5), pp.484-497.

Conservation International. 2018. Impact of climate change on tropical tuna species and tuna fisheries in Pacific Island waters and high seas areas. Information Paper for SAN 6003922 (CI-4).

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). 2019. Appendices I, II and III. Valid from 4 October 2017. https://www.cites.org/eng/app/appendices.php. Accessed 3/29/2019.

Coral Reef Research Foundation (CRRF). 2017. Sunscreen Pollution Analysis in Jellyfish Lake. Technical Report. 26 pp.

Coral Reef Research Foundation (CRRF). 2014. A Summary of Palau's Typhoon History. Technical Report, 17pp. www.coralreefpalau.org.

Costion, Craig. 2013. Conservation International Pacific Islands Program. Biodiversity Conservation Lessons Learned Technical Series 19: Threatened Endemic Plants of Palau.

Costion, C.M. and D.H. Lorence. 2012. The Endemic Plants of Micronesia: A Geographical Checklist and Commentary. Micronesica. 43(1): 51-100.

Costion, Craig, Jolie Liston, Ann H. Kitalong, Akiko Iida, and Andrew Lowe. 2012. Using the ancient past for establishing current threat in poorly inventoried regions. Biological Conservation. 147. 153–162. 10.1016/j.biocon.2011.12.026.

Crombie, Ronald I. and Gregory K. Pregill. 1999. A Checklist of the Herpetofauna of the Palau Islands (Republic of Belau), Oceania. Herpetological Monographs, Vol. 13 (1999), pp. 29-80.

Dalzell, P. T.J.H. Adams, and N.V.C. Polunin. 1996. Coastal Fisheries in the Pacific Islands. Oceanography and Marine Biology: an Annual Review 1996, 34, 395-531.

Dawson, M.N. 2005. Five new subspecies of *Mastigias* (Scyphozoa: Rhizostomeae: Mastigiidae) from marine lakes, Palau, Micronesia. J. Mar. Biol. Ass. U.K. 85:679-694.

Dawson, M.N and D.K. Jacobs. 2001. Molecular Evidence for Cryptic Species of *Aurelia aurita* (Cnidaria, Scyphozoa). Biol. Bull. 200: 92–96. .

Dawson, M.N., L.E. Martin and L.K. Penland. 2001. Jellyfish swarms, tourists, and the Christchild. 2001. Hydrobiologia 451:131-144.

Del Rosario, Aurora, Nelson M. Esguerra, and Thomas Taro. 2015. Taro Production in Palau. College of Micronesia Land Grant Programs: Kolonia, Pohnpei.

Delos Santos, Miguel. 2017. Mangrove Crabs. In: Rengiil, G., A.H. Kitalong, and M. Tsuchiya (eds). Paradise of Nature: Understanding the wonders of Palau. Palau International Coral Reef Center: Koror, Palau. Pp. 101-104.

Dendy, J., D. Mesubed, P. Colin, C. Giardina, and S. Cordell. 2019. Mapping fire on Babeldaob Island, Palau. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 24 p.

Dendy, Julian, Susan Cordell, Christian P. Giardina, Bernice Hwang, Edwin Polloi, and Kashgar Rengulbai. 2015. The role of remnant forest patches for habitat restoration in degraded areas of Palau. Restoration Ecology. 23(6): 872-881. https://doi.org/10.1111/rec.12268.

Division of Customs. 2017. Data and information provided specifically for the 2017 SOE.

Division of Forestry. 2018. Sustainable Forest Management (SFM) Policy. Draft National Policy. Ministry of Natural Resources, Environment and Tourism (MNRET).

Division of Oceanic Fishery Management (DOFM). 2017. Annual Report to the Western and Central Pacific Fisheries Commission (WCPFC). Raratonga, Cook Islands.

Division of Solid Waste Management (DSWM). 2017. Beverage Container Recycling Program Annual Report FY-2017.

Donato, D.C., J.B. Kauffman, R.A. Mackenzie, A. Ainsworth, and A.Z. Pfleeger. 2012. Whole-island carbon stocks in the tropical Pacific: Implications for mangrove conservation and upland restoration. Journal of Environmental Management 97 (2012) 89-96.

Donnegan, Joseph A., Sarah L. Butler, Olaf Kuegler, Brent J. Stroud, Bruce A. Hiserote, and Kashgar Rengulbai. 2007. Palau's Forest Resources, 2003. Resour. Bull. PNW-RB-252. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 52 p.

eBird. 2019. Website and Data Portal. Data access granted by request. https://ebird.org/region/PW.

Engbring, J. 1992. A 1991 Survey of the Forest Birds of the Republic of Palau. U.S. Fish & Wildlife Service, Honolulu, HI.

Environmental Quality Protection Board (EQPB). 2019. Water Quality Monitoring Data provided specifically for this report.

Environmental Quality Protection Board (EQPB). 2019b. Summary of EQPB Monitoring. Unpublished.

Environmental Quality Protection Board (EQPB). 2018. FY2018 Permit Application Summary.

Environmental Quality Protection Board (EQPB). 2016. Annual Summary Report: Permit Applications Fiscal Year 2016.

Environmental Quality Protection Board (EQPB). 2013. EQPB Regulations Current as of February 25, 2013. Chapter 2401-1 EARTHMOVING REGULATIONS. https://www.palaugov.pw/wp-content/uploads/2017/05/EQPB-Regulations-Feb-2013.pdf.

Estavillo C., R. Pardini, P.L. Rocha. 2013. Forest Loss and the Biodiversity Threshold: An Evaluation Considering Species Habitat Requirements and the Use of Matrix Habitats. PLoS ONE 8(12): e82369. doi:10.1371/journal.pone.0082369.

Etibek, Selby P. 2017. Recycling Rate (as of December 2016). Unpublished report.

FIA Data (Forest Inventory and Analysis) Data. 2014. Access Database. Downloaded from https://www.fs.fed.us/pnw/rma/fia-topics/inventory-data/. Accessed February 2017.

FIA Data (Forest Inventory and Analysis) Data. 2003. Access Database. Downloaded from https://www.fs.fed.us/pnw/rma/fia-topics/inventory-data/. Accessed February 2017.

Fisheries Development Assistance for Pacific Island Nations (FDAPIN). 1994. Report on implementation of second FDAPIN project (1993/94 Phase-2). Tokyo: Overseas Fishery Cooperation Foundation.

Food and Agriculture Organization (FAO). 2009. Fishery and Aquaculture Country Profile. http://www.fao.org/fishery/facp/PLW/en. Accessed November 2016.

Food and Agriculture Organization (FAO). 2014. Linking farmers to markets: Realizing opportunities for locally produced food on domestic and tourist markets in Palau.

US Forest Service. 2017. Forest Health 2016 Highlights.

US Forest Service. 2014. Forest Dynamics Monitoring in Palau. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd516182.pdf.

Friedlander, A.M., Y. Golbuu, E. Ballesteros, J.E. Caselle, M. Gouezo and D. Olsudong D. 2017. Size, age, and habitat determine effectiveness of Palau's Marine Protected Areas. PLoS ONE 12(3): e0174787. https://doi.org/10.1371/journal.pone.0174787.

Gillett, R.D. 2016. Fisheries in the Economies of Pacific Island Countries and Territories. Pacific Community (SPC), BOFM (2015) and FFA (2015).

Global Environment Facility-5 (GEF5). 2014. Project Document: R2R: Advancing Sustainable Resources Management to Improve Livelihoods and Protect Biodiversity in Palau. https://www.thegef.org/sites/default/files/project_documents/GEF_5_PALAU_Project_Document.pdf.

Global Environment Facility-6 (GEF6). 2018. Project Document: Integrating Biodiversity Safeguards and Conservation into Planning and Development. https://www.thegef.org/sites/default/files/project_documents/5-16-2018_ProDoc_2nd_Resubmission_A.pdf.

Golbuu, Y. 2000. Status of the coral reefs of Palau. PCC-CRE Publication 19/00.

Golbuu Y., J. Andrew, S. Koshiba, G. Mereb, A. Merep, D. Olsudong, B. Silil, and S. Victor. 2012. Status of Sea Cucumber Populations at Ngardmau State. PICRC Technical Report 12-01. Palau International Coral Reef Center. Koror, Palau.

Golbuu, Y., Eric Wolanski, Peter Harrison, Robert H. Richmond, Steven Victor, and Katharina E. Fabricius. 2011. Effects of Land-Use Change on Characteristics and Dynamics of Watershed Discharges in Babeldaob, Palau, Micronesia. Journal of Marine Biology, vol. 2011, Article ID 981273. doi:10.1155/2011/981273.

Golbuu Y., A. Bauman, J. Kuartei, and S. Victor. 2005. The state of coral reef ecosystem of Palau. pp. 488-507. In: J. Waddell (ed.), The state of coral reef ecosystems of the United States and Pacific freely associated states: 2005. NOAA Technical Memorandum NOS NCCOS 11, NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeograpy Team. Silver Spring, MD. 522pp.

Golbuu, Y., Garry Mereb, Dannie Uehara, Andrew Bauman, and Jack Umang. 1999. Biological Survey at Ngerumkaol, Koror State, Republic of Palau. Koror: PCC and Department of Conservation and Law Enforcement.

Gouezo, M., Y. Golbuu, K. Fabricius, D. Olsudong, G. Mereb, V. Nestor, E. Wolanski, P. Harrison, and C. Doropoulos. 2019. Drivers of recovery and reassembly of coral reef communities. Proceedings of the Royal Society B: Biological Sciences 286:10.

Gouezo M., and D. Olsudong. 2018. Impacts of Tropical Storm Lan (October 2017) on the western outer reefs of Palau. PICRC Technical Report 18-08 Palau International Coral Reef Center. Koror, Palau.

Gouezo M., E. Otto, R. Jonathan, L. Marino, G. Mereb, V. Nestor, D. Olsudong, and A. Parker. 2018. Ngemai Conservation Area 2018 follow-up ecological assessment. PICRC Technical Report 18-17 Palau International Coral Reef Center. Koror, Palau.

Gouezo M., V. Nestor, M. Dochez, R. Jonathan, L. Marino, D. Olsudong, and G. Mereb. 2018 Status of seagrasses fishes and macro-invertebrates at Teluleu Conservation Area from 2011 to 2018. PICRC Technical report 18-13 Palau International Coral Reef Center. Koror, Palau.

Gouezo, M., V. Nestor, D. Olsudong, L. Marino, G. Mereb, R. Jonathan, and Y. Golbuu. 2017. 15 years of coral reef monitoring demonstrates the resilience of Palau's coral reefs. PICRC Technical Report 17-01. Palau International Coral Reef Center (PICRC), Koror, Palau.

Gouezo M., S. Koshiba, E. Otto, D. Olsudong, G. Mereb, and R. Johnathan. 2016. Ecological conditions of coral-reef and seagrass marine protected areas in Palau. PICRC Technical Report 16-06. Palau International Coral Reef Center, Koror, Palau.

Gouezo M., P. Rechellul, and G. Mereb. 2016b. 2016 Stock assessment of Trochus niloticus in Palau. PICRC Technical Report 16-14. Palau International Coral Reef Center and Bureau of Marine Resource.

Gouezo M., Y. Golbuu, R. van Woesik, L. Rehm, S. Koshiba, and C. Doropoulos. 2015. Impact of two sequential super typhoons on coral reef communities in Palau. Mar Ecol Prog Ser 540:73–85.

Gouezo, M., Lincoln Rehm, Shirley Koshiba, Geory Mereb, Dawnette Olsudong, Randa Jonathan. 2014. Baseline Assessment of Ngerumekaol Spawning Area. PICRC Technical Report No. 15-01.

Hajkowicz, Stefan. 2003. Estimates of Fish Catch Loss Resulting from land-based pollution (2003). https://palau-data.sprep.org/dataset/fish-catch-loss-resulting-land-based-pollution.

Hanich, Quentin, Colette C.C. Wabnitz, Yoshitaka Ota, Moses Amos, Connie Donato-Hunt, and Andrew Hunt. 2018. Small-scale fisheries under climate change in the Pacific Islands region. Marine Policy 88 (2018) 279–284.

Harbourne, Alastair. 2016. The Nature Conservancy's Mapping Ocean Wealth Project: Modelling and mapping fishing pressure; the current and potential standing stock of coral-reef fishes in five jurisdictions of Micronesia. The Nature Conservancy and University of Queensland.

HIES. 2014. Household Income and Expenditure Survey. Office of Planning and Statistics, Ministry of Finance.

Holm, Tarita. 2015. A survey of post-fire vegetation in tropical anthropogenic savanna areas on Babeldaob Island, Republic of Palau. Master of Science Thesis. University of London.

Horii, Daisuke. 2018. Annual Report of DCLE Birds and Bats Monitoring Project in RISL (Reporting period: October 2017–September 2018). DCLE Birds and Bats Monitoring Report #15. Koror State Department of Conservation and Law Enforcement.

Horii, Daisuke and Milang Eberdong. 2018. Report on the First Saturday Birdwatch at the Long Island Park in 2018. Koror State Government and Belau National Museum.

International Monetary Fund (IMF). 2019. Republic of Palau: 2018 Article IV Consultation—Press release; Staff report; and Statement by the Executive Director for the Republic of Palau. February 2019. IMF Country Report No. 19/43.

International Union for the Conservation of Nature (IUCN). 2019. Red List of Threatened Species. www.redlist.org.

Island Conservation (IC). 2018. Historic Project to Protect Palau's Iconic Species Declared Successful: Free from invasive rats, native plants and animals on Ngeanges are on a path to recovery. Press Release. https://www.islandconservation.org/historic-project-protect-palaus-iconic-species-declared-successful/. Accessed 3/2/2019.

Kauffman, J. Boone and Thomas G. Cole. 2010. Micronesian Mangrove Forest Structure and Tree Responses to a Severe Typhoon. Wetlands (2010) 30:1077–1084.

Kauffman, J. Boone, Chris Heider, Thomas G. Cole, Kathleen A. Dwire, Daniel C. Donato. 2011. Ecosystem Carbon Stocks of Micronesian Mangrove Forests. Wetlands (2011) 31:343–352.

Ketebengang, Heather and Anuradha Gupta. 2011. State of Palau's Birds 2010: A conservation guide for communities and policymakers. Koror: Palau Conservation Society.

Kitalong, A.H. 2017. A perspective of fisheries management in Palau. In: Rengiil, G., A.H. Kitalong, and M. Tsuchiya (eds). Paradise of Nature: Understanding the wonders of Palau. Palau International Coral Reef Center: Koror, Palau. Pp. 196-204.

Kitalong, A.H. 2013. Republic of Palau Draft National Report, Millennium Development Goals (MDG). UN Sustainable Development Goals Knowledge Platform.

Kitalong, A.H. 2012 National Water Outlook. Ministry of Natural Resources, Environment and Tourism. EU Integrated Water Resource Management Project.

Kitalong, A.H. 2010. SWARS: The Republic of Palau Statewide Assessment of Forest Resources and Resource Strategy: A comprehensive analysis of forest-related conditions, trends, threats and opportunities. Koror: Bureau of Agriculture, Forestry Section.

Kitalong, A.H. and P. Dalzell. 1994. A preliminary assessment of the status of inshore coral reef fish stocks in Palau. Inshore Fish. Res. Tech. Doc. No. 6, South Pacific Commission, Noumea, New Caledonia.

Kitalong, A.H., Maireng Sengebau, and Tiare Holm. 2015. Achieving Resilient Agriculture and Aquaculture: A national policy for strengthening food security in Palau as a priority climate change adaptation measure. Koror: Palau Pacific Adaptation to Climate Change (PACC) program.

Koshiba, S., K. McNamara, M. Gouezo, E. Otto, and R. Jonathan. 2016-a. Socioeconomic Baseline Study of Kayangel State. PICRC Technical Report 16-11. Palau International Coral Reef Center, Koror, Palau. .

Koshiba, S., K. McNamara, M. Gouezo, E. Otto, and R. Jonathan. 2016-b. Socioeconomic Baseline Study of Ngchesar State. PICRC Technical Report 16-10. Palau International Coral Reef Center, Koror, Palau.

Koshiba, S., K. McNamara, M. Gouezo, E. Otto, and R. Jonathan. 2016-c. Socioeconomic Baseline Study of Ngiwal State. PICRC Technical Report 16-09. Palau International Coral Reef Center, Koror, Palau.

Koshiba, S., K. McNamara, M. Gouezo, E. Otto, and R. Jonathan. 2016-d. Socioeconomic Baseline Study of Peleliu State. PICRC Technical Report 16-08. Palau International Coral Reef Center, Koror, Palau.

Koshiba, S., K. McNamara, M. Gouezo, E. Otto, and R. Jonathan. 2016-e. Socioeconomic Baseline Study of Ngaraard State. PICRC Technical Report 16-07. Palau International Coral Reef Center, Koror, Palau.

Koshiba, S., M. Besebes, K. Soaladaob, A.L. Isechal, S. Victor, and Y. Golbuu. 2013. Palau's taro fields and mangroves protect the coral reefs by trapping eroded fine sediment. Wetland Ecology and Management, 21: 157-164.

Lehodey, P., J. Hampton, R.W. Brill, S. Nicol, and others. 2011. Vulnerability of oceanic fisheries in the tropical Pacific to climate change. In: JD Bell, JE Johnson and AJ Hobday (eds) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the Pacific Community, Noumea, New Caledonia, pp. 433–492.

Lindfield, S., 2017. Palau's reef fisheries: changes in size and spawning potential from past to present. Coral Reef Research Foundation: Koror, Palau.

Lindfield, S., 2016. Summary of the 2015 fishery creel and market survey in Palau. Coral Reef Research Foundation: Koror, Palau.

MacKenzie, Richard A, Patra B. Foulk, J. Val Klump, Kimberly Weckerly, Joko Purbospito, Daniel Murdiyarso, Daniel C. Donato, Vien Ngoc Nam. 2016. Sedimentation and belowground carbon accumulation rates in mangrove forests that differ in diversity and land use: a tale of two mangroves. Wetlands Ecol Manage (2016) 24:245–261.

MacNeil, Aaron, Nicholas A. J. Graham, Joshua E. Cinner, Shaun K. Wilson, Ivor D. Williams, Joseph Maina, Steven Newman, Alan M. Friedlander, Stacy Jupiter Nicholas V. C. Polunin, and Tim R. McClanahan. 2015. Recovery potential of the world's coral reef fishes. Nature 520, 341-344.

Marino, L. and R. Jonathan. 2018. Socioeconomic Baseline Study of Angaur State. PICRC Technical Report 19-01 Palau International Coral Reef Center. Koror, Palau.

Marino, L. and R. Jonathan. 2018 Socioeconomic Baseline Study of Melekeok State. PICRC Technical report 18–06 Palau International Coral Reef Center. Koror, Palau.

Marino, L., D. Olsudong, G. Mereb, and R. Jonathan. 2019. Socioeconomic Baseline Assessment of Koror State. PICRC Technical Report 19-05 Palau International Coral Reef Center. Koror, Palau.

Marino, L., M. Gouezo, M. Dochez, V. Nestor, R. Jonathan, G. Mereb, and D. Olsudong. 2018 Ecological Assessment of Ngermedellim Marine Sanctuary. PICRC Technical report 18-09 Palau International Coral Reef Center. Koror, Palau.

Marino, L., M. Gouezo, M. Dochez, V. Nestor, E. Otto, R. Jonathan, G. Mereb, O. Dawnette, and A. Parker. 2018 Ecological assessment of Iuaiu Conservation Area in Angaur State. PICRC Technical report 18-18 Palau International Coral Reef Center. Koror, Palau.

Marino, L., K. McNamara, M. Gouezo, and R. Jonathan. 2017 Socioeconomic Baseline Study of Airai State. PICRC Technical report 17-02 Palau International Coral Reef Center. Koror, Palau.

Marino, L., M. Gouezo, and R. Jonathan. 2017 Socioeconomic Baseline Study of Ngatpang State. PICRC Technical report 17-03 Palau International Coral Reef Center. Koror, Palau.

Marino, S., A. Bauman, J. Miles, A. Kitalong, A. Bukurow, C. Mersai, E. Verheij, I. Olkeriil, K. Basilius, P. Colin, S. Patris, S. Victor, W. Andrew, and Y. Golbuu. 2008. The state of coral reef ecosystem of Palau. pp. 511-539. In: J.E. Waddel and A.M. Clarke (eds.), The State of Coral Reef Ecosystems on the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569pp.

Martin, L.E., M.N. Dawson, L.J. Bell and P.L. Colin, 2006. Marine lake ecosystem dynamics illustrate ENSO variation in the tropical western Pacific. Biol. Lett. 2(1): 144-147.

Matthews, Elizabeth. 1992. The role of women in the fisheries of Palau. Internship Report. Oregon State University, Corvallis, OR.

McClanahan, T.R., J.M. Maina, N.A.J. Graham, and K.R. Jones. 2016. Modeling Reef Fish Biomass, Recovery Potential, and Management Priorities in the Western Indian Ocean. PLoS ONE 11(5): e0154585. doi:10.1371/journal.pone.0154585.

McClanahan, Tim, Nicholas Graham, Jacqulyn Calnan, and M. Aaron MacNeil. 2007. Toward Pristine Biomass: Reef fish recovery in coral reef Marine Protected Areas in Kenya. Ecological Applications, 17(4), 2007, pp. 1055–1067.

McGregor, Andrew, Leonard Basilius, and Thomas Taro. 2012. The Palau PACC Food Security Project: A Benefit Cost Analysis.

McKechnie, S., G. Pilling, and J. Hampton. 2017. Stock assessment of bigeye tuna in the western and central Pacific Ocean. Annual report to the Commission. Western and Central Pacific Fisheries Commission, Scientific Committee 13th Regular Session. Raratonga, Cook Islands: August 9-17, 2017. .

McKechnie, S., J Hampton, G. M. Pilling, and N. Davies. 2016. Stock assessment of skipjack tuna in the western and central Pacific Ocean. Annual report to the Commission. Western and Central Pacific Fisheries Commission, Scientific Committee 12th Regular Session. Bali, Indonesia: August 3-11, 2016. .

Mereb, G., M. Gouezo, R. Johnatan, D. Odsulong, A. Isechal.2016. The importance of long-term monitoring to assess the effectiveness of seagrass beds within a marine protected areas network in Palau, Micronesia. ICRS 2016 Poster.

Mersai, Charlene. 2007. Report on Mangrove Phytosociology Survey 2006-2007: Baseline Assessment of Palau's Mangrove Plants' Distribution and Abundance. PICRC. Unpublished.

Metz, William. 2000. The Palau Mangrove Management Plan (Volume 1 and Volume 2). Koror: Bureau of Natural Resources and Development, Ministry of Resources and Development.

Micronesia Challenge (MC). 2018. Republic of Palau Terrestrial Measures Indicator Summaries. https://mcterrestrialmeasures.org/#/palau.

Miles, Joel E. 2017. The Macaque Monkey problem in Palau. In: Rengiil, G., A.H. Kitalong, and M. Tsuchiya (eds). Paradise of Nature: Understanding the wonders of Palau. Palau International Coral Reef Center: Koror, Palau. Pp. 62-65.

Ministry of Education (MOE). 2016. Education Statistical Yearbook.

Ministry of Health (MOH). 2019. Dengue Information (Weekly Reports). http://www.palauhealth.org/MOHpages/MOHDengueSituation1.aspx.

Ministry of Health (MOH). 2017. Maternal and Child Health Services Title V Block Grant Palau. FY 2018 Application/FY 2016 Annual Report.

Ministry of Health (MOH). 2017b. Palau Hybrid Survey Final Report.

Ministry of Natural Resources, Environment and Tourism (MNRET). 2019. Updates from the Ministry. January-March 2019 Edition.

Ministry of Natural Resources, Environment and Tourism (MNRET). 2018. Updates from the Ministry. Monthly Newsletters. https://www.palaugov.pw/mnret-monthly-newsletter/.

Ministry of Natural Resources, Environment and Tourism (MNRET). 2017. Tuna Fisheries Strategic Plan 2017–2021. Koror, Palau.

Miyakuni, Kaoruko, Yoko Fujita, Lincy Marino, and Geraldine Rengiil. 2018. Developing Carrying Capacity for Marine Tourism: The Case of the Republic of Palau. PICRC Technical Report 18-15.

Moore, Brad, Percy Rechelluul and Steven Victor. 2015. Creel survey and demographic assessments of coastal finfish fisheries of southern Palau: September 2014. Secretariat of the Pacific Community (SPC).

Mumby, P., Y. Bozec, G. Roff, M. Gouezo, C. Doropoulos, and Y. Golbuu. 2018 Status Report on Ngederrak and Lighthouse Reef. PICRC Technical report 18-14 Palau International Coral Reef Center. Koror, Palau.

National Development Bank of Palau (NDBP). 2011-2017. Financial Statements and Independent Auditor's Report. Multiple available on https://www.ndbp.com/about-us/financial-statements.

National Oceanic and Atmospheric Administration (NOAA). 2019. Seasonal Coral Bleaching Heat Stress Outlook (CFS-based). https://coralreefwatch.noaa.gov/satellite/bleachingoutlook_cfs_v4/bleachingoutlook_weekly_90.php.

NBSAP. 2014. The Republic of Palau Revised National Biodiversity Strategy and Action Plan 2015-2025. Prepared by the Palau Conservation Society (PCS) for the Office of Environmental Response and Coordination (OERC).

Nestor, V., E. Otto, M. Gouezo, L. Marino, G. Mereb, D. Olsudong, R. Jonathan, J. Swords, Y. Golbuu. 2017 Impacts of snorkelers on shallow coral reefs in the Rock Island Southern Lagoon. PICRC Technical report 17-04 Palau International Coral Reef Center. Koror, Palau.

Neville, Rachel. 2014. Current forest conditions in the US-Affiliated Pacific Islands. US Forest Service.

Ngellil: (Kesolei, O.K.). 2018. Nature Island Resort Environmental Assessment.

Northern Reefs Fisheries Cooperative (NRFC). 2018. Palau Northern Reef Fish Landing Survey Database_2018_28_March.

NREL (National Renewable Energy Laboratory, US Department of Energy). 2016. Palau Energy Factsheet.

NREL (National Renewable Energy Laboratory, US Department of Energy). 2015. Palau Energy Snapshot.

OceanHealthIndex.com. 2017. Methodology. http://www.oceanhealthindex.org/methodology. Accessed March 2017.

Oiterong, Zilah D. and Kathy Sisior. 2018. Annual report to the Commission. Western and Central Pacific Fisheries Commission, Scientific Committee 14th Regular Session. Busan, Korea: August 8-16, 2018. .

Olsen, Alan and Milang Eberdong. 2014. A rapid field assessment of the Rufous Night-Heron population of Palau, Micronesia. Western Birds 45:231–235.

Olsen, Alan, Milang Eberdong, Heather Ketebengang, Princess Blailes, and Po-Hao Chen. 2016. Survey of Megapode Nesting Mounds in Palau, Micronesia. Western Birds 47:27–37.

Otto, E., M. Gouezo, L. Marino, V. Nestor, D. Olsudong, R. Jonathan, and G. Mereb. 2019. 2017 Ecological Assessment of Ngelukes Conservation Area. PICRC Technical Report 19-02 Palau International Coral Reef Center. Koror, Palau.

Otto, E., M. Gouezo, S. Koshiba, G. Mereb, R. Jonathan, D. Olsudong, and Y. Golbuu. 2016. Impact of Snorkelers on Shallow Coral Reef Communities in Palau. PICRC Technical report 16-15. Palau International Coral Reef Center. Koror, Palau.

Otto, Judy. 2008. Palau: A Situation Analysis of Children, Youth & Women. UNICEF Pacific Office, Fiji.

PACCSAP (Pacific-Australia Climate Change Science and Adaptation Planning Program). 2015. Current and future climate of Palau. Australia: Palau National Weather Service Office, Australian Bureau of Meteorology, and Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Pacific Islands Secretariat Forum. 2018. First Quadrennial Pacific Sustainable Development Report. https://www.forumsec.org/wp-content/uploads/2018/10/First-Quadrennial-P.S.D.R.-Full-Report.pdf.

Pacific Islands Training Initiative (PITI). 2016. Republic of Palau Fiscal Year 2015 Economic Review. Graduate School USA, Economic Monitoring & Analysis Program.

Pakoa, Kalo, Ron Simpson, Lora Demei, Downette Olsudong, Cherryl Salong, Percy Rechelluul and David Fisk. 2014. The status of sea cucumber fisheries resources and management for Palau. Secretariat of the Pacific Community (SPC), Noumea, New Caledonia.

Pakoa, Kalo, Ferral Lasi, Emmanuel Tardy and Kim Friedman. 2009. The status of sea cucumbers exploited by Palau's subsistence fishery. Noumea: Secretariat of the Pacific Community (SPC).

Palau Automated Land and Resource Information System (PALARIS). 2019. Data, maps, and analysis provided specifically for the SOE Report.

Palau Automated Land and Resource Information System (PALARIS). 2017. Farm Survey. Data, maps, and analysis provided specifically for Palau's draft Concept Paper to the Global Climate Fund (GCF).

Palau Conservation Society (PCS). 2019. Kebeas Project 2017-2018. Unpublished report.

Palau Conservation Society (PCS). 2019b. Unpublished reports prepared for UNCBD 6th National Report.

Palau Energy Office. 2018. Data and information provided specifically for this 2019 SOE.

Palau Energy Office. 2017. Data and information provided specifically for the 2017 SOE.

Palau Public Utilities Coorporation (PPUC). 2017. Independent Auditors' Report on Internal Control and on Compliance. Year ended September 30, 2017.

Palm Springs: (NECO Group). 2018. Palm Spring Resort: An Environmental Assessment on a proposed first class, five-star resort at Ngerur Island, Koror, Palau.

Patris, S.W., L.E. Martin, L.J. Bell, and M.N Dawson. 2019. Expansion of an introduced sea anemone population, and its associations with native species in a tropical marine lake (Jellyfish Lake, Palau). Frontiers of Biogeography. In press. DOI:10.21425/F5FBG41048

Patris, S.W., M.N Dawson, L.J. Bell, L.E. Martin, P.L. Colin, and G. Ucharm. 2012. Ongeim'l Tketau: Jellyfish Lake. Coral Reef Research Foundation and Etpison Museum: Koror, Palau. 44 pp.

PECI: (Madrangchar, Marhence). 2018. Environmental Impact Assessment for the Proposed Development, Improvement and Relocation Project for a Site at M-Dock Location in Medalaii Hamlet of Koror State of the Republic of Palau.

Pojas, Rhealyn. 2019. Move to delay PNMS implementation to impact international status: PICRC. Island Times article. http://islandtimes.us/move-to-delay-pnms-implementation-to-impact-intl-status-picrc/. Accessed 2/25/2019.

Poonian, Chris, Patricia Z. R. Davis, and Colby Kearns McNaughton. 2010. Impacts of Recreational Divers on Palauan Coral Reefs and Options for Management. Pacific Science 64(4). https://doi.org/10.2984/64.4.557.

Prince, Jeremy, Steven Victor, Valentino Kloulchad, Adrian Hordyk. 2015. Length based SPR assessment of eleven Indo-Pacific coral reef fish populations in Palau. Fisheries Research 171 (2015) 42–58.

Protected Areas Network (PAN) Fund. 2017. Annual Report, Fiscal Year 2017.

Protected Areas Network (PAN). 2015. PAN Status Report 2003-2015. palaugov.pw/wp-content/uploads/2016/10/PAN-Status-Report-2003-2015.pdf.

Radley, Paul M. 2019. Projected Sea Level Rise and the Conservation Ecology of the Micronesian Megapode (*Megapodius laperouse senex*) in Palau, Micronesia. PhD Thesis. School of Science, Edith Cowan University.

Rehm, L., S. Koshiba, G. Mereb, D. Olsudong, F. Siksei, and K. Remeliik. 2014. Status of sea cucumber populations inside and outside a Marine Protected Area in Ngardmau State, Palau. PICRC Technical Report 14-10. Palau International Coral Reef Center. Koror, Palau.

Rengiil, G., A.H. Kitalong, and M. Tsuchiya (eds). 2017. Paradise of Nature: Understanding the wonders of Palau. Palau International Coral Reef Center: Koror, Palau.

Republic of Palau (ROP). FY2017 to FY2018. Quarterly Economic Indicators (multiple files). https://www.palaugov.pw/executive-branch/ministries/finance/budgetandplanning/quarterly-economic-indicators/. Additional year's reports used in 2017 SOE.

Rhodes, K.L., K. Warren-Rhodes, P. Houk, J. Cuetos-Bueno, Q. Fong, and W. Hoot. 2011. An Interdisciplinary Study of Market Forces and Nearshore Fisheries Management in Micronesia. A Report of the Marine Program of the Asia Pacific Conservation Region, The Nature Conservancy. Report No. 6/11. 120 pp.

Richey, J.N. and J.P. Sachs. 2016. Precipitation changes in the western tropical Pacific over the past millennium. Geology,44(8), pp.671-674.

Roff, C., S. Bejarano, M. Priest, A. Marshell, I. Chollett, R.S. Steneck, C. Doropoulos, Y. Golbuu, and P.J. Mumby. 2018. Seascapes as drivers of herbivore assemblages in coral reef ecosystems. Ecological Monographs, 0(0), 2018, pp. 1-17. http://onlinelibrary.wiley.com/doi/10.1002/ecm.1336/full. https://doi.org/10.5061/dryad.014sn6.

Sachs, J.P., J.L. Blois, T. McGee, M. Wolhowe, S. Haberle, G. Clark, and P. Atahan. 2018. Southward Shift of the Pacific ITCZ During the Holocene. Paleoceanography and Paleoclimatology 33:12, pp. 1383-1395.

Sachs, J.P., D. Sachse, R.H. Smittenberg, Z. Zhang, D.S. Battisti, and S. Golubic. 2009. Southward movement of the Pacific intertropical convergence zone AD 1400–1850. Nature Geoscience, 2(7), p.519.

Samimi-Namin, Kaveh, and Leen P. van Ofwegen. 2016. Overview of the genus *Briareum* (Cnidaria, Octocorallia, Briareidae) in the Indo-Pacific, with the description of a new species. ZooKeys 557: 1.

Sarmiento, J. L., R. Slater, R. Barber, L. Bopp, S. C. Doney, A. C. Hirst, J. Kleypas, R. Matear, U. Mikolajewicz, P. Monfray, V. Soldatov, S. A. Spall, and R. Stouffer. 2004. Response of ocean ecosystems to climate warming, Global Biogeochem. Cycles, 18, GB3003, doi:10.1029/2003GB002134.

Schramek, T.A., Colin, P.L., Merrifield, M.A. and Terrill, E.J., 2018. Depth-dependent thermal stress around corals in the tropical Pacific Ocean. Geophysical Research Letters, 45(18), pp.9739-9747.

SDG Report. 2018. Draft report on the Sustainable Development Goals. Prepared by the NEPC Secretariat, Ministry of Finance.

Secretariat of The Pacific Community (SPC). 2019. Pacific Ocean Portal, Ocean Monitoring, Ocean Temperature. http://oceanportal.spc.int/portal/app.html#climate.

Siksei, Fabio. 2018. Palau Dugong and seagrass. Presentation at the GEF Dugong and Seagrass Conservation Project meeting. Solomon Island: March 2018.

Sinniger, F., D. Ballantine, I. Bejarano, P. Colin, X. Pochon, S. Pomponi, K.A. Puglise, R. Pyle, M. Reaka, H. Spalding, and E. Weil. 2016. Biodiversity of mesophotic coral ecosystems. Mesophotic coral ecosystems—a lifeboat for coral reefs, pp.50-62.

SPREP (Richards, Esther). 2012. Waste Management Policies & Practices in Pacific Island Countries & Territories. PowerPoint presentation. Apia: SPREP.

SPREP. 2016. PALAU – Country Data Dossier for Reducing Risk of Extinction Summary Sheet. aichi-12-country-data-dossier-reducing-risk-of-extinction-summary.pdf.

Taylor, Brett, K. Rhodes, Alyssa Marshell, and Jennifer Mcilwain. 2014. Age-based demographic and reproductive assessment of orangespine *Naso lituratus* and bluespine *Naso unicornis* unicornfishes. Journal of Fish Biology. 85. 10.1111/jfb.12479.

Temengil, Baklai, and Ann Hillman Kitalong. 2014. The Republic of Palau National Review: Implementation of the Beijing Declaration and Platform for Action (1995); The Outcomes of the 23rd Special Session of the General Assembly (2000) in the context of the 20th Anniversary of the 4th World Conference on Women; and the Adoption of the Beijing Declaration and Platform for Action 2015. Ministry of Community and Cultural Affairs.

Terrill, E.J., M.A. Moline, P.J. Scannon, E. Gallimore, T. Shramek, A. Nager, R. Hess, M. Cimino, P.L. Colin, A. Pietruszka, and M.R. Anderson. 2017. Project Recover: Extending the Applications of Unmanned Platforms and Autonomy to Support Underwater MIA Searches. Oceanography, 30(2), pp.150-159.

The Nature Conservancy (TNC). 2018. Transforming the Last Tuna Stronghold. https://www.nature.org/en-us/about-us/where-we-work/united-states/california/stories-in-california/transforming-the-last-tuna-stronghold/. Accessed 4/29/2019.

The Nature Conservancy (TNC). 2015. Climate Projections and Impacts for the Republic of Palau.

The World Bank Climate Change Knowledge Portal. 2019. Climate Data, Historical, Precipitation, Average (by month). https://climateknowledgeportal.worldbank.org/country/palau/climate-data-historical. Accessed 1/28/2019.

TNC ERA (The Nature Conservancy Ecoregional Assessment): David Hinchley, Geoff Lipsett-Moore, Stuart Sheppard, Umiich Sengebau, Eric Verheij and Sean Austin). 2007. Biodiversity Planning for Palau's Protected Areas Network: An Ecoregional Assessment (ERA). TNC Pacific Island Countries Report No. 1/07.

Tremblay-Boyer, L., S. McKechnie, G. Pilling, and J. Hampton. 2017. Stock assessment of yellowfin tuna in the western and central Pacific Ocean. Annual report to the Commission. Western and Central Pacific Fisheries Commission, Scientific Committee 13th Regular Session. Raratonga, Cook Islands: August 9-17, 2017. .

UNCRD. Date unknown. Presentation "Solid Waste Management in Palau." Available at http://www.uncrd.or.jp/content/documents/RT4_03_Palau.pdf.

United Nations Convention to Combat Desertification (UNCCD). 2018. Report from Palau. https://prais.unccd.int/sites/default/files/pdf_reports/unccd_Palau_2018_0.pdf.

University of Hawaii Sea Level Center (UHSLC). 2019. Sea Level Trends. https://uhslc.soest.hawaii.edu/. Accessed 2/26/2019.

van Hooidonk, R, J. A. Maynard, and S. Planes. 2013. Temporary refugia for coral reefs in a warming world. Nature Climate Change 1829: 1-4. DOI: 10.1038.

van Woesik, R., Y. Golbuu, and G. Roff. 2015. Keep up or drown: adjustment of Pacific coral reefs to contemporary sea-level rise. Royal Society Open Science, DOI: 10.1098/rsos.150181.

van Woesik, R., Y. Golbuu, and G. Roff. 2015. Supplementary Document: Keep up or drown: adjustment of Pacific coral reefs to contemporary sea-level rise.

VanderWerf, E.A. 2007. 2005 Bird Surveys in the Republic of Palau. U.S. Fish & Wildlife Service, Honolulu, HI.

Wabnitz, C.C.C., A.M. Cisneros-Montemayor, Q. Hanich, and Y. Ota. 2018. Ecotourism, climate change and reef fish consumption in Palau: Benefits, trade-offs and adaptation strategies. Marine Policy, 88 323-332.

Ward, Raymond D., Daniel A. Friess, Richard H. Day, Richard A. MacKenzie. 2016. Impacts of climate change on mangrove ecosystems: a region by region overview. Ecosystem Health and Sustainability, 2:4, e01211, DOI: 10.1002/ehs2.1211.

Wenger, Amelia S., Mark I. McCormick, Geoffrey G. K. Endo, Ian M. McLeod, Frederieke J. Kroon, Geoffrey P. Jones. 2014. Suspended sediment prolongs larval development in a coral reef fish. Journal of Experimental Biology 2014 217: 1122-1128; doi: 10.1242/jeb.094409 .

William, Peter and Chris Reid. 2018. Overview of Tuna Fisheries in the Western and Central Pacific Ocean, including Economic Conditions – 2017. Western and Central Pacific Fisheries Commission, Scientific Committee 14th Regular Session. Busan, Korea: August 8-16, 2018.

Williams, B., B. Thibodeau, Y. Chikaraishi, N. Ohkouchi, A. Walnum, A.G. Grottoli, and P.L. Colin. 2017. Consistency in coral skeletal amino acid composition offshore of Palau in the western Pacific warm pool indicates no impact of decadal variability in nitricline depth on primary productivity. Limnology and Oceanography, 62(2), pp.399-407.

World Bank (Hoornweg, Daniel and Perinaz Bhada-Tata). 2012. What a Waste: A global review of solid waste management. Urban Development Series Knowlege Papers No. 15. Washington, DC: World Bank.

World Bank. 2019. Palau Data. https://data.worldbank.org/country/palau. Accessed 4/5//2019.

World Heritage Dossier. 2012. Rock Islands Southern Lagoon. https://whc.unesco.org/en/list/1386.

World Ocean Review. 2013. The Future of Fish – The Fisheries of the Future. https://worldoceanreview.com/en/wor-2/fisheries/illegal-fishing/2/.

Yuen, Y., M. Gouezo, and T. Nakamura. 2018 Coral Reef Communities in Palau's Inner Reefs. PICRC Technical report 18–02 Palau International Coral Reef Center. Koror, Palau.

ACKNOWLEDGEMENTS

Photo by B. Bintorio

This report was prepared by Anuradha Gupta of D&D Biodiversity Consulting on behalf of the Palau National Environmental Protection Council (NEPC).

National Environmental Protection Council (NEPC)
Minister F. Umiich Sengebau, Chair
Ministry of Natural Resources, Environment and Tourism

NEPC Secretariat
Charlene Mersai, National Environment Coordinator
Bureau of Budget and Planning, Ministry of Finance
palau.nepc@gmail.com

D&D Biodiversity Consulting
Anuradha Gupta
ddbiodiversity@gmail.com

Suggested Citation:
Gupta, Anuradha. 2019. 2019 State of the Environment Report, Republic of Palau. National Environmental Protection Council, Government of Palau: Koror, Palau. 102 pages.

Special thanks go to the following people for their help in providing text, data, references, assistance, photos, or a review:

- Dr. Pat Colin
- Lori Colin
- Dr. Ann Kitalong
- Steven Lindfield
- Julian "Spuns" Dendy
- Dr. Richard MacKenzie
- King Sam
- Heather Ketebengang
- Joe Chilton
- Kimie Ngirchechol
- Zina Wong
- Mike Aulerio
- Kulie Rengulbai
- David Idip
- Kyonori Tellames
- Joe Aitaro
- Amand Alexander
- Charlene Mersai
- Marine Gouezo
- Darlynne Takawo
- Dr. Yimnang Golbuu
- Leena Muller
- Dr. Jack Kittinger
- Javier Cuertos-Bueno
- Calvin Ikesiil
- Lolita Gibbons-Decherong
- Fred Sengebau
- Umai Basilius
- Andres Cisneros
- Yvonne Ueda
- Kathy Sisior
- Steven Victor
- Lalou Solang
- Lynna Thomas
- Siual Blesam
- Ben Crain

Photo by B. Bintorio

2019 State of the Environment Report
Republic of Palau

F. Umiich Sengebau
Chair
National Environmental Protection Council

Office of the Minister
Ministry of Natural Resources, Environment & Tourism
P.O. Box 100
Koror, Republic of Palau 96940

Photo courtesy of BWA/R2R

Prepared by Anuradha Gupta
D&D Biodiversity Consulting

This report was produced with support from the
Global Environment Facility (GEF) and the
United Nations Development Program (UNDP).