2017 State of the Environment Report
Republic of Palau

March 2017

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

by the National Environmental Protection Council (NEPC)

Dear President,

On behalf of the National Environmental Protection Council (NEPC), I am pleased to present you with this State of the Environment Report 2017. This report is monumental in being the first self-reported assessment of our nation's environmental conditions since independence. It thus presents perspectives on both our natural and man-made environment, and on our successes and challenges as a self-determined nation. This report is the first to synthesize scientific research into a single snapshot of our country and its direction.

I am happy to report that where we have invested significantly, such as in our Human/Urban Environment and in Protected Areas, we have good conditions and positive trends. Although our coral reefs have faced large disturbances, they seem to be recovering well. Unfortunately, many other natural resource indicators are in worse condition than they were in 1994, or trending the wrong way. This report verifies many of our perceived threats and indicates that particular effort is needed to conserve our fisheries and terrestrial resources.

This reports builds on a 1994 State of the Environment report that established our baseline, and incorporates more than two decades of monitoring and research. Given the massive amount of information available, this report provides you and the Palauan people with answers to the following select questions:

- What is the most recent condition of key indicators?
- How do these conditions relate to local and global goals or standards?
- What are key threats, pressures, and unmitigated risks to indicators?
- Where can one go for more information about environmental indicators, including the status of existing monitoring programs?

I, and the entire NEPC, look forward to working with you and our communities to continue programs that are working, address needs that are identified here, and "conserve the best, while improving the rest."

Sincerely,

Minister Umiich Sengebau
Chair
National Environmental Protection Council

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Introduction & Summary

Introduction and Intended Audience

This State of the Environment Report 2017 conveys the trend of key natural resource indicators through time, and analyzes their most recent condition in relation to local and global goals and standards. Where supported by evidence or consensus, it assigns a 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 uses the 1994 State of the Environment Report (Otobed and Maiava 1994) as a baseline and expands on indicators in that report. 1994 was when Palau gained independence, plus it serves as a baseline for a time before Climate Change began dramatically impacting the islands.

This report fulfills annual reporting requirements of the NEPC under Executive Order 350 (Special Reports submitted to the President). In addition to informing the President, this report is designed to:

- Guide the President and OEK in setting priorities.
- Guide agencies and organizations as they implement environmental efforts.
- Provide information to the public, particularly where support, improvement, and compliance are needed.
- Encourage researchers to fill data gaps.

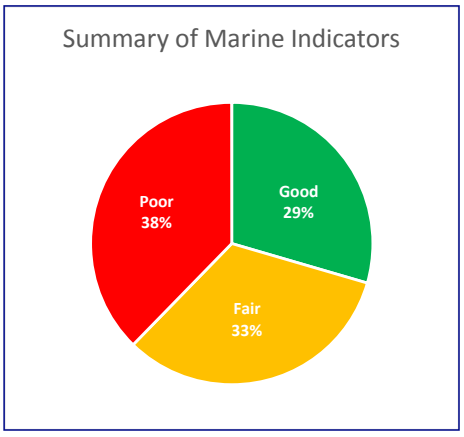
Summary

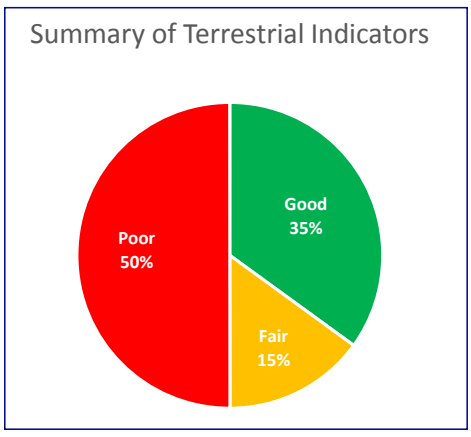
147 indicators were assessed; 121 (82%) had adequate information to assign a grade and/or determine a trend.

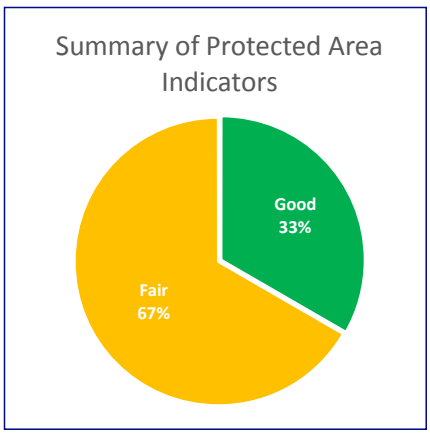
Over 69 individual and aggregate indicators were assessed to determine the state of the Marine Environment. 62% of indicators were in good or fair condition. 29 indicators showed clear trends; 59% were trending in a direction that is stable or benefits the environment. With the exeption of outer reefs on the East, Palau's reefs are in good condition and resilient. However, reef fisheries are in poor condition. Offshore fisheries are in good or fair condition.

There are many unknowns for Mangroves; total extent has increased but with complex impacts.

Over 20 indicators were assessed to determine the state of the Terrestrial Environment. 50% were good or fair. 19 showed trends; with 47% trending in a direction that

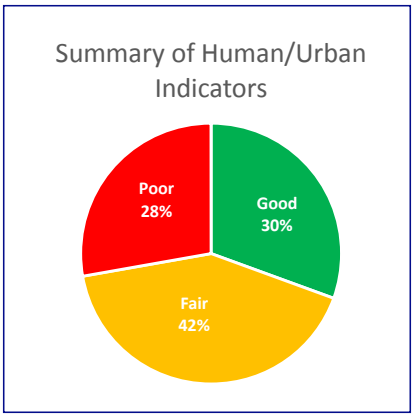






is beneficial to the environment. However, the Belochel (Micronesian Pigeon) is in immediate danger of local extinction. Forests offered bright points.

9 indicators on Protected Area (PA) Effectiveness showed that investment in PAs has paid off; all were fair or good.



Over 35 indicators were assessed on various sectors in the Human/Urban Environment: Water Quality & Sanitation, Water Supply, Earthmoving & Land Cover Change, Energy Sector & Transportation, Solid Waste & Recycling, Agriculture & Aquaculture, Education & Awareness, Environmental Health, and Alien Invasive Species. 72% of Human/Urban indicators received a grade of good or fair. 27 indicators showed clear trends, with the majority (60%) improving or trending in a desirable direction. The number of earthmoving permits showed a worrisome increasing trend.

Threats between 1994 and 2017 have changed in many ways, although three—1) unplanned development and sedimentation, 2) inadequate coordination across agencies, and 3) insufficient enforcement—have been constant challenges. Since 1994 water quality, sanitation services, chemical pollution, and solid waste management have greatly improved. In 1994 there were few concerns over overexploitation of terrestrial resources and only minor concern over damage to marine habitats and depletion of natural stocks. Overfishing, overharvesting, and damage to marine habitats are now major threats. New threats now include negative impacts from Climate Change and tourism growth, and insufficient capacity to keep up with new challenges in individual sectors.

This report highlights areas that need immediate (and at times drastic) additional effort, such as:

- Reduction of reef fishing pressure,
- Expansion or creation of new reef, seagrass, and terrestrial protected areas, with enforcement,
- Immediate and drastic reduction of (illegal) hunting pressure on Belochel,
- Reduced hunting pressure on large megafauna at risk of local extinction (turtles and dugong),
- Binding ridge-to-reef planning and compulsory practices to reduce sedimentation, and
- Monitoring to fill data gaps.

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. This report identifies government agencies responsible for monitoring natural resources, and highlights gaps. It guides users on where to go to get more in-depth information.

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 many Strategic Plans and from peer-reviewed 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—such as amount of land cover change, population change for megafauna species, and accurate reef fishery landings—are included in the conclusions. 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 instance, in Airai Bay, mangroves (a valuable nursery habitat) have increased; however, this was due to sedimentation and may possibly encroach on seagrass, which may be declining. Thus 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.

Reporting on every aspect of Palau's environment could easily form the basis of one's lifelong passion. Ideas for future State of the Environment analyses are provided in the Conclusions. This Report is just the starting point to making sound decisions. Our hope is that it will answer many questions, while also inspiring new ones.

Key to Color Codes

Condition: Good/Healthy. Populations are stable and/or sustainable or Ecosystems are functional and resilient (Rapport 1998); Environment allows human well-being (MEA 2005).
Trend: Beneficial to the environment.

Condition: Fair. Populations and/or ecosystem functions could improve in condition but are not declining.

Condition: Poor/Not healthy. Populations below stable or sustainable levels, or Threatened; Ecosystems not functioning in natural state; Environment hinders well-being.
Trend: Harmful to the environment.

Condition: 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.

Coral Reefs

Summary and Major Points

PICRC kindly provided most of the information in this section.

Palau's reefs underpin the country's tourism sector and provide fish and seafood for sustainable and commercial use.

Most coral reefs are able to bounce back from disturbances; East coast reefs have been degraded

The status of Palau's reefs varies widely by location and over time. Since 1994 there have been four massive mortality events (1998 mass bleaching event, 2010 thermal stress event, and 2012 and 2013 Bopha and Haiyan Supertyphoons) leading to declines in live coral cover in some places. The 1998 bleaching event strongly impacted Palau's coral reefs with more than half of corals completely bleaching (Bruno et al. 2001). A decade later, 2010's minor thermal stress event induced some bleaching but corals were resistant and bleaching did not induce mass coral mortality (vanWoesik et al. 2012). In 2012 and 2013, Supertyphoons Bopha and Haiyan each damaged the entire stretch of eastern reefs from Kayangel to Angaur (Gouezo et al. 2015).

Coral reefs recovered well from the 1998 bleaching event (Golbuu et al. 2007, Golbuu et al. 2013), with most reefs reaching close to their maximal coverage about a decade later (around 2009). Today, despite chronic disturbances such as overfishing and sedimentation, close to 60% of all coral reefs are in good to very good condition and resilient. Only the outer eastern reefs have lingering impacts from typhoon wave damages. These reefs are expected to take longer than a decade to recover because of the complete loss of their habitat structure.

Some inner reefs, such as those in Nikko Bay, host isolated and unique corals that live in unusually acidic environmental conditions (Golbuu et al. 2016). Environmental conditions in Nikko Bay (pH and temperature) are already close to conditions that are predicted to occur throughout Palau by 2100 due to Climate Change. These reefs are already adapted to acidic waters and thus expected to be resilient under future Climate Change scenarios.

Coral reefs need additional protection

The often-quoted value that Palau has protected over 40% of its marine environment hides the true fact that coral reefs with full protection are far below necessary thresholds to maximize their resilience. The 40% value includes management zones such as the Rock Islands Southern Lagoon which is not entirely a no-take zone and includes areas that do not have reef. Only 14% of Palau's coral reefs and seagrass beds are no-take zones.

Indicator	State		Trend	Grade
2014 Live Coral Cover by Habitat	*% Live Coral Cover*	*Score*		
Inner Bay Reef - 3 m	50%	5	Stable	Good
Inner Bay Reef - 10 m	37%	4	Stable	Good
Outer Reef East - 3 m	6%	1	Unknown	Very Poor
Outer Reef East - 10 m	5.7%	1	Unknown	Very Poor
Outer Reef West - 3 m	29%	4	Stable	Good
Outer Reef West - 10 m	55%	5	Stable	Very Good
Patch Reef - 3 m	30%	4	Increasing	Good
Patch Reef - 10 m	17%	2	Increasing	Poor

Notes on Trend: See Figure, p. 8. Coral cover has been monitored since 2001 as part of PICRC's long-term coral reef monitoring program.

Indicator: *2014 Live Coral Cover, aggregated* [1]	**Live Coral Cover: 3 m depth, weighted average of all habitats**	**Live Coral Cover: 10 m depth, weighted average of all habitats**	**Live Coral Cover: Nationwide, weighted average of all habitats**
State:	2014 Score: 4	2014 Score: 3	2014 Score: 4
Grade:	Good	Fair	Good

[1]*To get the overall score, individual scores for each habitat was weighted considering the total area of the habitat. No trend can be presented here as data is specific to the habitat and depth presented above.*

Basis for Grade: Scores and the grading system were developed 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, 1=Very Poor (<10% cover), 2=Poor (10%<coral cover<20%), 3=Fair (20%<coral cover <30%), 4= Good (30%<coral cover<40%), 5=Very Good (> or = 50%). For all other habitats and depths, 1=Very Poor (<8% cover), 2=Poor (8%<coral cover<16%), 3=Fair (16%<coral cover <24%), 4= Good (24%<coral cover<32%), 5=Very Good (> or = 40%).

All information on this page from Gouezo (2017, PICRC Monitoring Report, unpublished).

PICRC Monitoring Programs

The Palau International Coral Reef Center (PICRC) is a semi-government autonomous institution. PICRC has conducted regular monitoring of Palau's reefs since late 2001 to assess change in coral reef and fish communities over time and over large spatial scales. Surveys are conducted at 23 permanent monitoring sites located around Palau within 3 coral reef habitats: outer reef, patch reef, and inner reef. Coral reef monitoring protocols are described in several published studies (Golbuu et al. 2007 & 2016; Barkley et al. 2015; Gouezo et al. 2015). At each site and depth (3 m and 10 m), five 50-m transects were haphazardly placed following the depth contour of the reef, leaving a few meters in between transects. Along each transect, data on benthic coverage, fish abundance and size, and juvenile coral density and size were recorded.

Indicator	Location	Trend	Grade
Live Coral Cover: Recovery over time	**Inner Bay Reef**	Stable	Good
	Outer Reef East	Unknown	Very Poor
	Outer Reef West	Stable	Good
	Patch Reef	Increasing	Fair

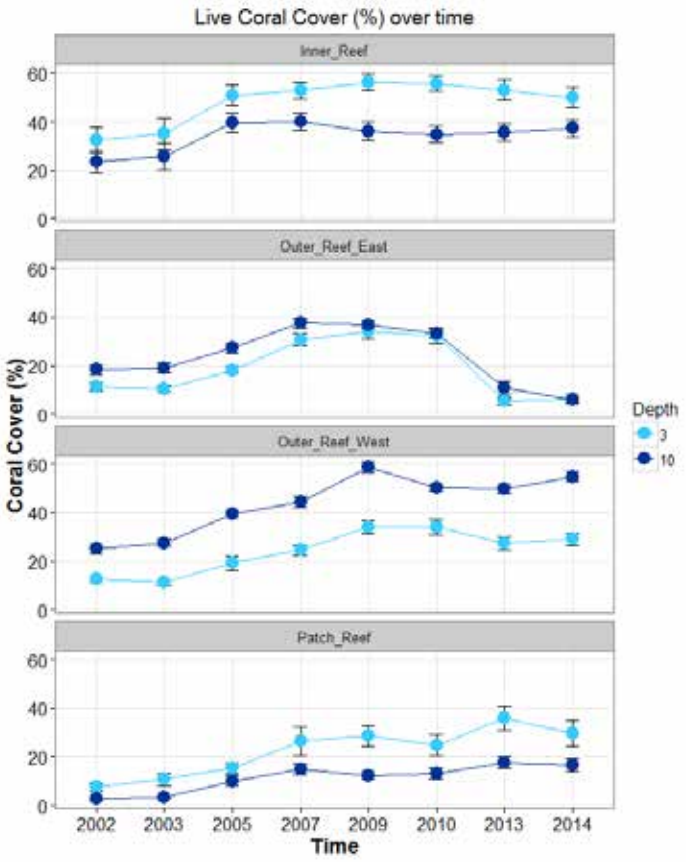
State:

- There are significant differences in coral cover change over time in each habitat and depth; they naturally differ.
- Live coral is higher on inner and patch reefs at 3 m depth because of low wave exposure.
- Inner reefs either were less impacted by the 1998 bleaching or recovered faster from bleaching than other reef habitats. Inner reefs reached their carrying capacity in 2005, whereas outer reefs reached capacity around 2009 (11 years after bleaching).
- The outer reefs on the East coast were heavily damaged by Supertyphoons Haiyan and Bopha (Gouezo et al. 2015).
- Patch reefs seemed to have been the most impacted by 1998's bleaching and it is unclear if they are fully recovered; coral cover is still slowly increasing.

(Gouezo 2017, PICRC Monitoring Report, unpublished).

Notes on trend: See Figure, right and text above. Recovery rate depends on location and natural differences.

Basis for Grade: Subjective. Some locations have declined (due to large mortality events such as typhoons) and for some locations, recovery time may be longer than the space of time between bleaching events. Another widespread bleaching event occurred in 2010, with an average of 30% of coral bleaching, but with low mortality.



Live percentage coral coverage over time (±SE) within the main reef habitats of Palau.

Indicator	State	Trend	Grade
Percentage of Reefs with "High" Coral Cover (over 50%)	2014: • 60% of reefs had High coral cover[2] • 27% of reefs had Medium coral cover • 13% of reefs Severely Degraded. (Gouezo 2017, PICRC Monitoring Report, unpublished)	**Stable or Increasing** (Reefs with Medium or High live coral cover) **Unknown** (Severely Degraded Reefs[3])	**Good**

[2] "High" defined as having over 50% live coral cover. "Medium" defined as having between 25 and 50% live coral cover. "Severely Degraded" defined as having less than 10% live coral cover. The proportion of reefs was calculated using PICRC's long-term coral reef monitoring data and extrapolated to areas that were not surveyed but had similar habitat type and exposure.
[3] Trends for Severely Degraded reefs (less than 10% coral cover) are not known, but are being monitored.

Notes on trend: See Figure, p8. There have been increases in the number of sites with High Coral Cover from 2005, when 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).

Basis for Grade: 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.

Coral Disease (Prevalence and Number of diseases)	2014 and 2016: • No coral disease noted during reef monitoring surveys (Gouezo 2017, PICRC Monitoring Report, unpublished)	**Stable**	**Good**

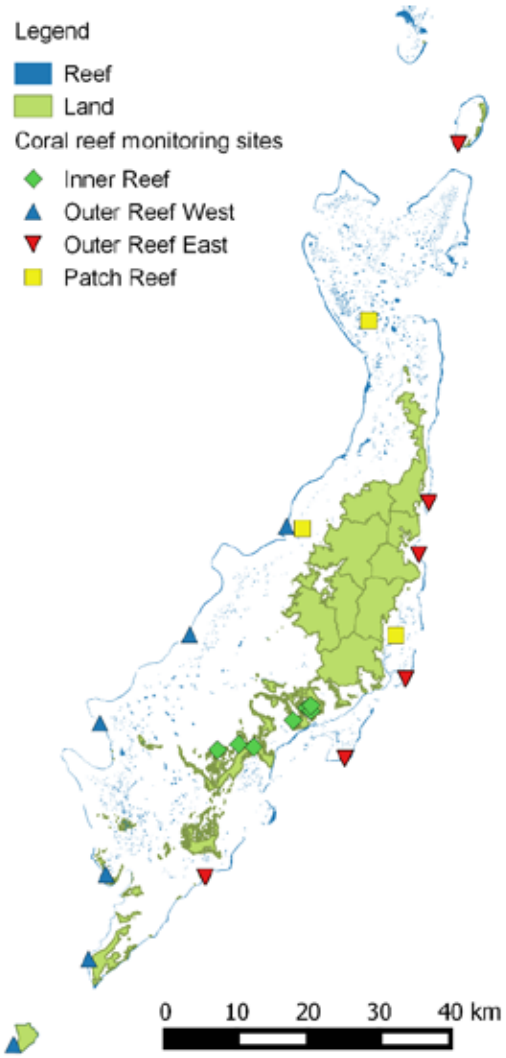
Notes on trend: In Golbuu 2000 only one (1) coral disease was noted. In 2004 disease affected 1 to 5.28% of colonies; 12 diseases and syndromes were reported (Marino et al. 2008).

Basis for Grade: Relative to disease presence in other Pacific reefs, as given in Aeby et al. 2011: Presence of indicator diseases on 5.3% of colonies in Hawaii, 53.7% on *Porites* colonies in Philippines, and 2.8-8.9% of colonies in Guam. 12 Syndromes reported in Hawaii (impacted and pristine reefs) in 2004-2005.

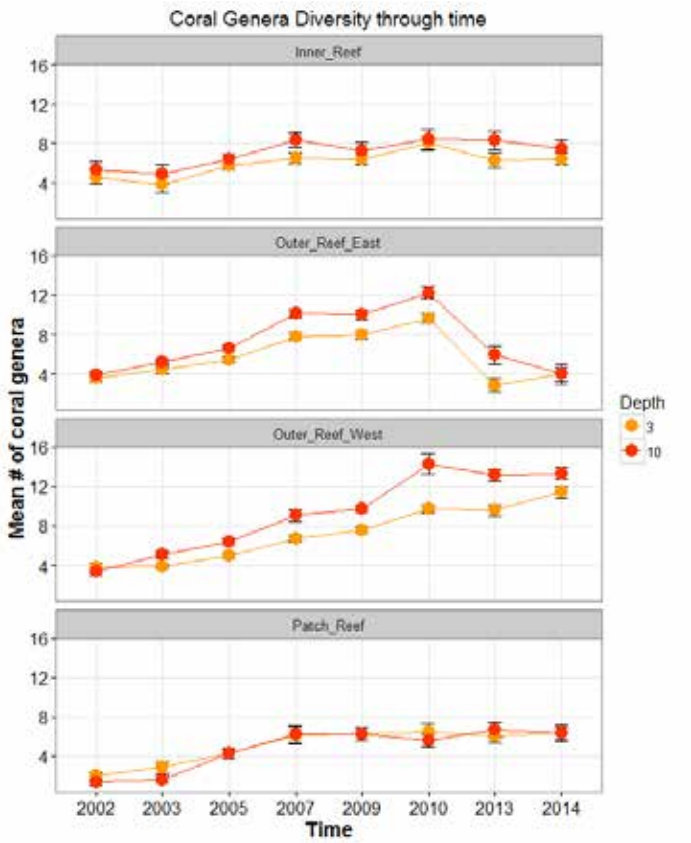
Indicator	State	Trend	Grade
Coral Genus Diversity	• Genus diversity increased as coral reefs recovered from bleaching. • Highest genus diversity is found on the Western outer reef. It was also high on the Eastern outer reef before the 2012 and 2013 typhoons. • Patch reefs have the lowest coral genera diversity. • Total coral genera recorded throughout time is 54. There is no site with this level of genus diversity. • Coral communities differ within each reef habitat. (Gouezo 2017, PICRC Monitoring Report, unpublished).	**Stable** (Outer Reef West, Inner Reef, & Patch Reef) **Unknown** (Outer Reef East)	**Good** (Outer Reef West, Inner Reef, & Patch Reef) **Poor** (Outer Reef East)

Notes on trend: See Figure below and text. Recovery rate depends on location and natural differences.

Basis for Grade: Subjective, based on genera present compared to past high values.



Map of PICRC's long term coral reef monitoring sitess, 2016



Change in the number of coral genera through time (±SE) within each habitat and depth

Indicator	Total outer reef protected	Total channel habitat protected	Total back reef protected	Lagoon and reef flats protected
State	2014: 25.7%	2014: 29%	2014: 16.8%	2014: < 10%
Grade	Fair (64% to ERA goal)	Fair (52% to ERA goal)	Poor (42% to ERA goal)	Poor (<25% to ERA goal)
All values from Gouezo et al. (2016)	Desired protection threshold = **40%** [4]	Desired protection threshold = **50 to 60%** [4]	Desired protection threshold = **40%** [4]	Desired protection threshold (Lagoon and Seagrass) = **40%** [4]

[4] 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.

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%.

Pressures and Unmitigated Risks

The main pressures and threats to coral reefs come from overfishing, sedimentation from land, and the daily cumulative plus long-term impacts of Climate Change (Appendix 1). Efforts to mitigate these threats have included awareness raising, regulations on sustainable fish sizes fishing practices, seasonal closures, efforts to build political consensus for land use planning, and widespread support for protected areas. However, these risks are still not fully mitigated. Lesser threats (such as direct damage from anchors) have been mitigated, but as of yet the needed primary solutions—reduced reef fishing, land use planning, erosion control measures, improved enforcement of MPAs, and some reef rehabilitation (where appropriate)—have not been implemented comprehensively.

Learning more about coral reefs

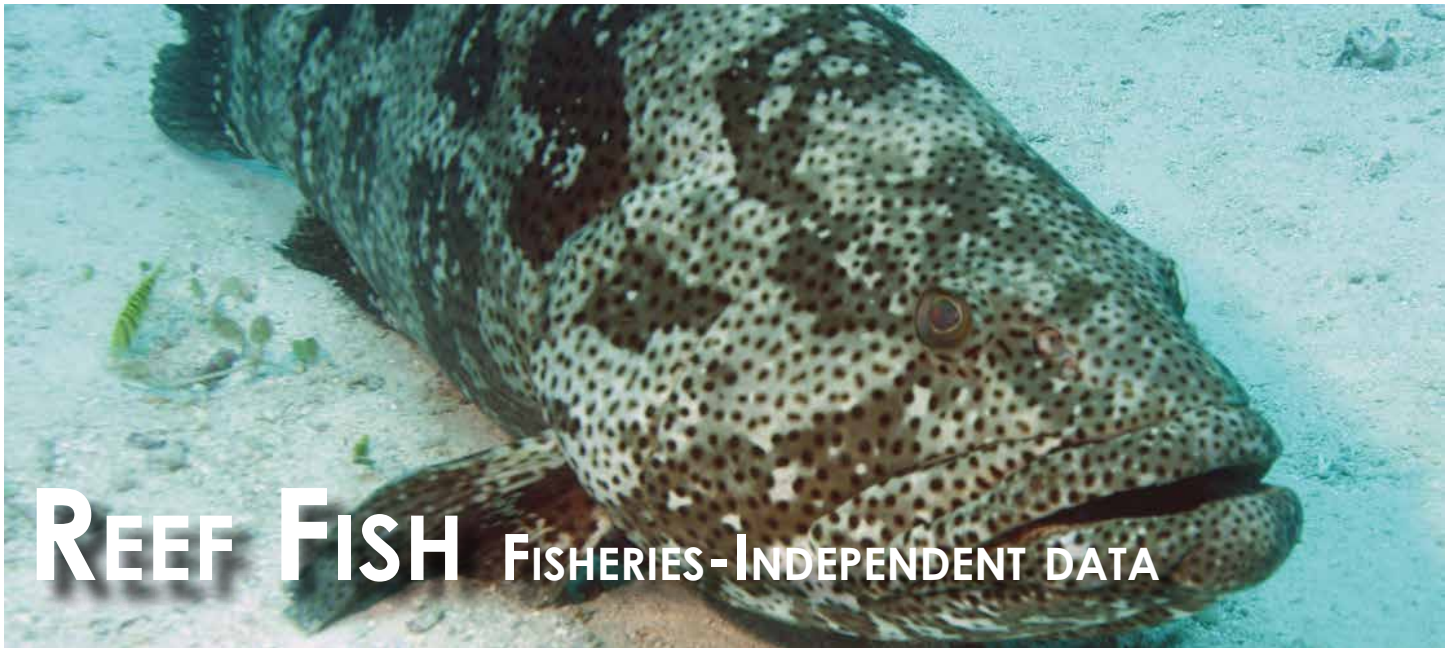
PICRC is the primary location in Palau to learn about Palau's reefs based on the indicators reported here.

The Coral Reef Research Foundation (CRRF) also has plentiful information on sites throughout Palau, and has partnered closely with Koror State. The Helen Reef Resource Management Project has data for Hatohobei. State Conservation Officers are slowly building their data collections (on paper and digitally) of protected reefs in their states. Currently there is little sharing of this data.

Monitoring Programs and Gaps

PICRC maintains a network of monitoring sites around Palau. CRRF also regularly monitors reefs for water temperature, collects information on species diversity and biogeography, and monitors marine lakes for temperature, salinity, and oxygen fluctuations, water clarity, and censuses of zooplankton and jellyfish populations (CRRF website). Some individual states have advanced monitoring programs for protected sites that include reef, such as Koror and Hatohobei. Most other states rely on PICRC to monitor their reefs. The US National Oceanic and Atmospheric Administration (NOAA) monitors Palau's reefs via satellite to determine risk of bleaching. Data is available online on the Coral Reef Watch website.

CRRF's monitoring data is not readily accessible to the public. Although Palau is a hotspot of research from international researchers, there is no clearinghouse for publications and data arising from these (assumingly permitted) research studies. While PICRC has been monitoring protected status of reefs, they are not mandated to do so. The Palau Protected Areas Network (PAN) Office is only mandated to monitor PAN sites, thus there is no agency with the mandate to track total reef protected area and type. An online database of publications as part of the Coral Reef Information System webpage for Palau is outdated.



Reef Fish Fisheries-Independent Data

Summary and Major Points

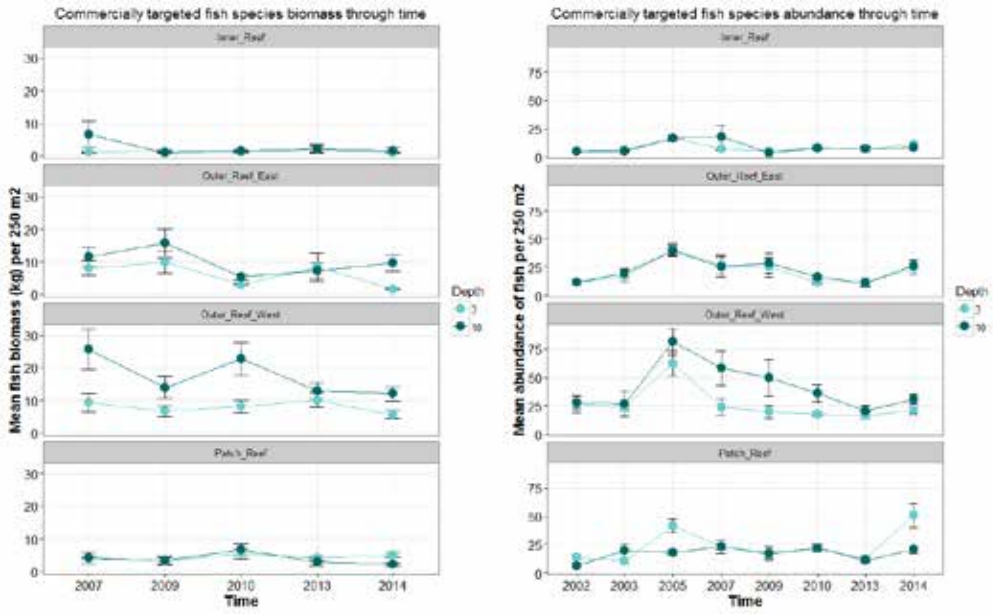
PICRC kindly provided most of the information in this section.

Reef fish are in decline

Abundance and biomass of fish are declining. Many species may be near crash points. Declines are primarly due to overfishing and then Climate Change.

Risks to reef fish are not adequately mitigated

Despite establishment of protected areas, the Protected Areas Network, National Marine Sanctuary, and rules and regulations on harvest seasons and sizes, fish are declining. These efforts have not reduced overfishing, especially the amount of fish taken. Only 14% of total coral reef and seagrass areas are fully protected; either the area protected is insufficient or MPAs are not enforced adequately to protect reef fish so that they can replenish unprotected reefs and sustain fish populations.



Change in commercially-targeted fish biomass (left) and species abundance (right) (±SE) through time within different reef habitats and depth (Gouezo 2017, PICRC Monitoring Report, unpublished).

Learning more about reef fish

Although the Bureau of Marine Resources should hold information on reef fish, it does not have much fisheries data. PICRC currently maintains information on reef fish in coral reef and seagrass habitats. CRRF monitors some Spawning and Aggregation sites (SPAGS), particularly for grouper. Nongovernment organizations like Palau Conservation Society, TNC, and Ebiil Society, have significant data on fish from past and current projects.

Indicator	State	Trend	Grade
Standing biomass, Exposed reefs	2016: 453 kilograms/ hectare (See Figure on p. 12, left)	No Clear Trend	Fair (63% of expected)
Standing biomass, Exposed MPAs	2016: 714 kg/ha (See Figure on p. 39, top)	Increasing	Good (defined as Good; see basis)
Standing biomass, Sheltered reefs	2016: 149 kg/ha (See Figure on p. 12, left)	No Clear Trend	Fair (57% of expected)
Standing biomass, Sheltered MPAs	2016: 258 kg/ha (See Figure on p. 39, top)	Increasing	Good (defined as Good; see basis)

All biomass values above provided by Golbuu (2016, PICRC data, unpublished).

Basis for Grade: PICRC monitoring protocols focus on commercially-important fish and do not count all fish. Thus there is no local standard by which to compare Palau's reefs. In Ngemelis, biomass in some locations was over 3000 kg/ha (Friedlander et al. 2014), but this is considered a very unique location. References by McClanahan and MacNeil are useful as guides, noting that their studies examined outer reefs. According to these references, which are based on a global meta analysis (and the closest location used to Palau was Guam), 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.

Using Harbourne's definitions and setting the MPA values as the expected biomass, these grades 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 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.

Abundance of commercially targeted and protected fish species through time	2002-2014: • Higher on outer reefs than sheltered reefs • Very low abundance on inner reefs • Declines predominantly on outer reef west (See Figure on p. 12, right)	Declining	Poor

Notes on trend: Data has lots of variability, both due to observers and natural variability (Gouezo 2017, PICRC Monitoring Report, unpublished).

Basis for Grade: Subjective. Very low numbers in sheltered reefs and declining trend on outer reefs.

Pressures and Unmitigated Risks

Overfishing for commercial purposes increases pressure on reef fish, combined with the occasional loss of live coral cover. Analysis of expected versus actual biomass growth rate indicates that Climate Change is responsible for only about 30% of the decline in reef fish (Gupta and Padilla 2017, GCF Application, unpublished). Overfishing is thus responsible for the majority of declining trends in reef fish. Risks to reef fish are largely unmitigated. While there have been campaigns and rules put in place to regulate the size of reef fish taken and minimize poaching in some MPAs, there have been few efforts implemented to reduce the amount of fish taken overall. With the exception of temporary closure seasons for groupers and rabbitfish, fishing regulations designed to reduce overall harvest levels are lacking. Explained in the previous section, protection of marine habitats is only poor to fair, and thus inadequate to protect reef fish populations.

Indicator	State	Trend	Grade
Grouper Populations/ SPAGs (Spawning and Aggregation Sites)	2011 and 2015: • Three species of grouper more abundant at protected SPAGs (Ngerumekaol & Ebi-il) than at unprotected SPAGs (Denges & Ngeremlengui). • Abundance of two species increased at protected SPAGs (Golbuu and Friedlander 2011, Gouezo et al. 2015)	**Declining** (Unprotected SPAGs) **Increasing/Stable** (Protected SPAGs)	**Poor** (Unprotected SPAGs) **Fair** (Protected SPAGs)

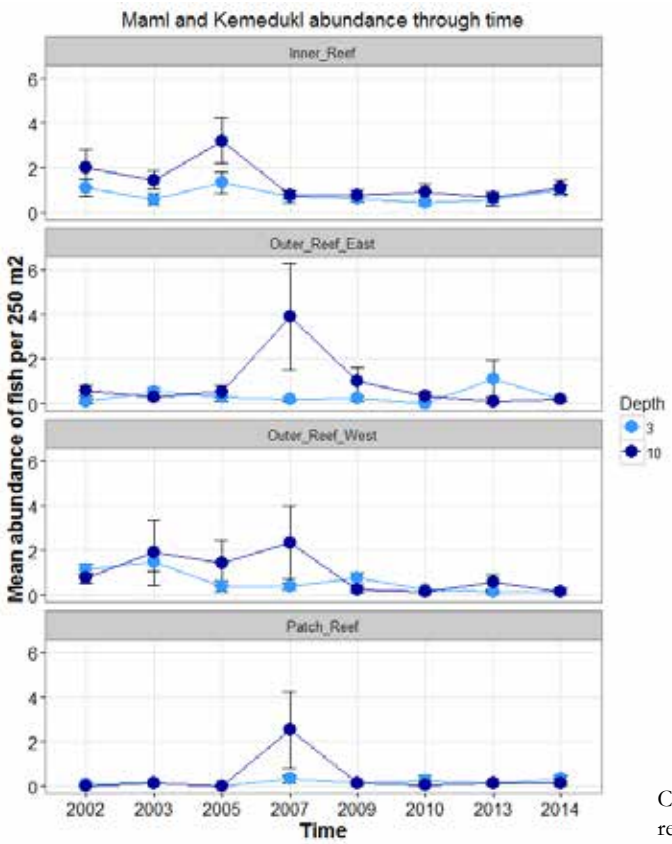
Notes on trend: "Spectacular" declines from 1990s to 2000s (Golbuu & Friedlander 2011) although Colin et al. (2013) indicated no such declines. An extension on a harvest ban was approved; the Grouper closing season is now open from April 1 to October 31.

Basis for Grade: Subjective. At protected spawning and aggregation sites (SPAGS), three grouper species accounted for 78% of the abundance and 85% of the biomass of all resource species surveyed but comprised <1% of the total abundance and biomass at reference sites not protected from fishing that formally harbored spawning aggregations; combined with Channel Habitats Protected indicator showing only 29% of channels protected (see p. 9).

Indicator	State	Trend	Grade
Populations of Maml and Kemedukl	2014: • Estimated Kemedukl: 62,000 • Estimated Maml: 37,000 (Polloi et al. 2014) 2002-2014: • Populations quite low, little growth (See Figure below) • Sampling design not adapted to determine trend (Gouezo 2017, PICRC Monitoring Report, unpublished)	**No Clear Trend**	**Poor**

Notes on trend: Polloi et al. (2014) found an increase in population, but recommended keeping both fisheries closed. If opened (not recommended), the highly-regulated maximum annual harvest would be: Kemedukl = 487 fish and Maml = 129 fish. Poaching is known to occur.

Basis for Grade: Subjective. Fish population and biomass still below values in 1990s, when the population was larger. Possible (highly regulated) sustainable take (if any, no take recommended) would be 30 to 40% below take in 1990s (Maximum recommended take (if at all) for Maml = 1222 kg/yr; 1990s harvest averaged 1731 kg/yr. Maximum recommended take for Kemedukl = 4922 kg/yr; 1990s harvest averaged 8547 kg/yr). Maximum take numbers are small (on the order of 10-11 Maml per month); opening the fishery may lead to overfishing.



Change in abundance of Maml and Kemedukl (±SE) through time within different reef habitats and depth.

Monitoring Programs and Gaps

PICRC monitors fish as part of its regular monitoring program. This monitoring protocol is not designed to assess Maml and Kemedukl, which have been assessed through individual research studies. CRRF also monitors fish, including research on SPAGs.

The lack of capacity at BMR to monitor reef fish, or manage data collected by others, is a major gap. The largest repositories on reef fish are semi- and nongovernment organizations, who lack the mandate or resources to monitor and report on them regularly.

Reef Fisheries Fisheries-Dependent data

Summary and Major Points

Reef fisheries are in trouble

Reef fish are being fished at an unsustainable rate. Fish are being removed from the reefs faster than they can reproduce. Many species are harvested while immature.

Some fisheries regulations been successful

Past efforts to minimize commercial export and to regulate the size of fish caught (e.g. with net size restrictions) have improved fisheries. The ban in maml and kemedukl is allowing those species to recover.

Information on reef harvests is poor

Best estimates of reef fish harvests rely on data from 2000 and a mix of recent data from fish markets and ad hoc surveys. It is currently not possible to determine a true sustainable fishing rate for reef fish, and even more difficult to determine it by location.

Indicator	State	Trend	Grade
Reef Fish Harvest—Overall	2016: • Estimated fishing take = 2115 metric tons/year (2000-present). • No certain measurements of fishing take, most estimates rely on survey from 2000 (Gillet 2016). • Surveys suggest it is harder to find fish (Moore et al. 2014). 2013-2016: • Overharvesting of herbivorous fish that have important functional role for coral reef health (Bejarano et al. 2013, Harborne et al 2016).	**Increased from 1994; now possibly Declining**	**Poor**

Notes on trend: 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 Dalzel 1994). By 2000 fish were being harvested at the rate of over 2000 mt/yr, which appears to be unsustainable. See other indicators in this section; which suggest a likely decline from this 2000 mt/yr value due to difficulty finding reef fish.

Basis for Grade: Subjective. Considers multiple indicators that suggest overfishing is occurring.

Indicator	State	Trend	Grade
Quantity of Fish Caught/ Fish Abundance	2014: 73% of fishers stated that the quantity of fish caught had decreased over the last five years. (Moore et al. 2014)	**Declining**	**Poor**
		Basis for Grade: Subjective. Continued trend and large percentage of the public finding it difficult to find fish.	
Reef Fish Exported (Commercial, Personal, and Added Value)	2015: 103 metric tons (mt) • 11.2 mt whole frozen (commercial); • 87.3 mt whole frozen (personal); • 4.5 mt added-value (Calculated from BMR Annual Marine Export Report 2015)	**Declining**	**No Grade Assigned** No standards or goals on which to base grade
		Notes on trend: Clear decrease from earlier years. In 2011, 213 ± 60 mt/yr was exported (Rhodes et al. 2011 in Gillet 2016). In the early 2000s, 400 mt/yr was exported (FAO 2009).	
Size of Reef Fish caught—Overall	2014: Low number of immature individuals observed in current catches *However,* 2014: 80% of fishers said size of fish had decreased over past 5 years. (Moore et al. 2014) 2016: Fisheries landings in the Northern Reefs confirmed that most species were not immature sizes (except Kedesau and Um) (Lindfield et al. 2016)	**Increasing or Stable** (Some species declining)	**Fair**
		Notes on trend: "Significant reduction in the proportion of smaller fish compared to approximately 25 years ago" (Moore et al. 2014). *Basis for Grade:* Moore et al. (2014) conclude that "results from this baseline assessment suggest that coastal finfish fisheries appear to be moderately healthy" p. 22. However, fishers reported that fish sizes had decreased, and for some key species (see next indicator), small immature fish are harvested.	
Erangel: Fishing sustainability	2014: Overfished. Fishing mortality more than double the recommended maximum fishing mortality rate (Moore et al. 2014)	**Unknown** Possibly increasing	**Poor**
Chum (Um): Fishing sustainability	2014: Not yet overfished, but close. Fished near a maximum recommended level (Moore et al. 2014)	**Unknown** Possibly increasing	**Fair**

Notes on trend: Overfishing likely increasing (due to increased fishing and decreased productivity of reefs due to Climate Change).

Basis for Grade: Good: Fishing rate above maximum fishing mortality rate (not reported here, see Moore et al. for full list). Fair: Fishing rate close to maximum fishing mortality rate. Poor: Fishing rate above maximum mortality rate.

Indicator	State	Trend	Grade
Size of Reef Fish Caught/Species with a large proportion caught immature:	**Keremlal** (50% of catch immature)	Declining[5]	Poor
	Klsebuul (23% of catch immature)	Declining[5]	Fair

All 2014 (Moore et al. 2014)

[5] *Notes on trend:* For Keremlal and Klsebuul, significant decline in length frequencies from 1991-1992 to 2014: reduction in large fish, increase in smaller fish, and shift in length to smaller fish (Moore et al. 2014).

Species	Beyadel/ Ngesngis	Udoudungelel	Ngyaoch/ Berkism	Kotongel/ Kedesau	Melangmud
State	(42% of catch immature)	(85% of catch immature)	(39% of catch immature)	(91% of catch immature)	(50% of catch immature)
Grade	Fair	Poor	Fair	Poor	Poor

Basis for Grade: Subjective. Fish at risk of overfishing. Poor = > 50% of catch immature. Fair = 49 to 15% of catch immature.

Reef Fish going to restaurants	2017: >94 metric tons (Ann Singeo/Ebiil Society 2017, unpublished)	Increasing No basis to determine benefit or harm	No Grade Assigned No standards or goals on which to base grade

Notes on trend: In the early 1990s, the measured amount going to restaurants was 22 mt/yr (PCS 2000); by the mid 2000s this was likely at least 55 mt/yr (calculated from PCS 2000 as a direct factor of tourism growth; tourism increased 250% between mid-1994 and the mid-2000s).

Pressures & Unmitigated Risks

High demand for reef fish—for daily food, to feed and entertain an increasing number of tourists, and to meet large customary needs during traditional events (possibly with waste)—are driving overfishing. Impacts of Climate Change (e.g. loss of live coral cover; Appendix 1) also contribute to declines in fish; yet the fishery sector is only slowly adapting to reduced supply. Reef fish are still exported and thus not meeting local food security needs. Several of the overfished species have no or inadequate regulatory protections; or are underrepresented in MPAs. Approximately 22% of Palauan households fish on reefs exclusively (do no offshore fishing; calculated from the 2014 HIES). They are thus reliant on an ever-dwindling resource for their subsistence and/or income.

Learning more about reef fisheries

There is inadequate regulatory authority on reef fisheries, and government investment in reef fisheries has been minimal. Estimates of exports are determined by BMR. The Ebiil Society has collected recent fishery data, but only in select locations and as part of a short-term project. TNC, PCS, and PICRC also have fisheries projects.

Monitoring Programs and Gaps

PICRC has just started monitoring reef fisheries through underwater and store surveys. For many years there was no long-term program to monitor reef fisheries and estimate harvest, which created a major gap in understanding Palau's reefs and food security. Although BMR monitors exports at the airport, it does not physically weigh or inspect every cooler/package, thus export values are estimates. Several foreign researchers have reconstructed fisheries data; they have all relied on PCS surveys from 2000.

Offshore Fisheries

Summary and Major Points

Bigeye Tuna are overfished

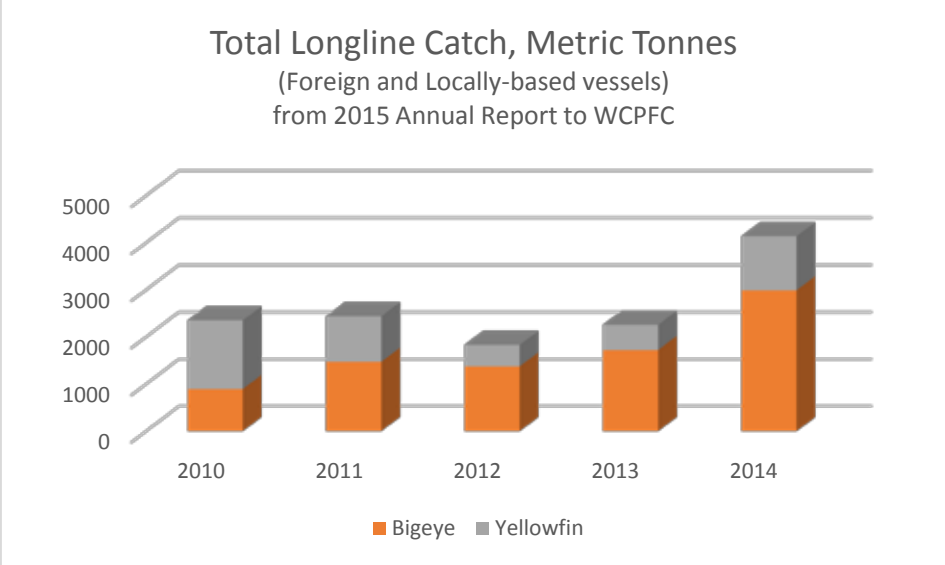
In the Western Pacific, Bigeye Tuna are being fished at above Maximum Sustainable Yield (MSY).

Climate Change will reduce tuna populations

Climate Change is expected to create short-term decreases of 4% for Bigeye and Yellowfin; and much larger decreases (up to 45%) in the long-term.

Reductions under the PNMS will yield positive benefits to local and regional stocks

Closing offshore fisheries to all but domestic fishers within a 20% Domestic Fishing Zone will mitigate for the expected reductions from Climate Change, reduce risks of overfishing above MSY, and still meet local food needs and tourist desires.



Learning more about offshore fisheries

The Division of Offshore Fisheries within the Bureau of Marine Resources keeps data on offshore fish catches, vessels, licenses, and observer records. These are reported to the Western & Central Pacific Fisheries Commission (WCPFC).

The Palau National Marine Sanctuary is also an authority on Palau's offshore environment.

Indicator	State	Trend	Grade
Average Bigeye Tuna Catch	2010-2014: • Average 1700 mt/yr • (Range: 897-2995 mt/yr). (Calculated from Bureau of Oceanic Fishery Management 2015/WCPFC Report)	Increasing	Poor

Notes on trend: Catch in 2014 was almost double that in years prior. Palau has no limit on this species. Bigeye (and by extension yellowfin) is expected to decrease under all scenarios from a short-term decrease of 4% to a long-term decrease of 11 to 45% (Lehody et al. in Bell et al. 2011).

Basis for Grade: Total Bigeye Catch in the Western Pacific is over MSY (Harley et al. 2014 / SPC Stock Assessment).

Average Yellowfin Tuna Catch	2010-2014: Average 730 mt/yr (Range: 456-1459 mt/yr) (Calculated from Bureau of Oceanic Fishery Management 2015).	No Clear Trend	Fair

Notes on trend: 2014 catch was double year prior; but not highest in the period. Bigeye (and by extension yellowfin) is expected to decrease under all scenarios from a short-term decrease of 4% to a long-term decrease of 11 to 45% (Lehody et al. in Bell et al. 2011).

Basis for Grade: Total Yellowfin Catch in the Western Pacific is nearing MSY (Davies et al. 2014 / SPC Stock Assessment).

Average Skipjack Catch (Purse Seine)	2010-2014: Average 840 mt/yr (Range: 0 to 2825 mt/yr). (Calculated from Gillet 2016)	No Clear Trend	Good

Notes on trend: 2014 was four (4) times higher than prior highest catch. In the short-term (2035) skipjack populations in Palau may increase by 10% but by 2100 may decline by as much as 27% (Lehody et al. in Bell et al. 2011).

Basis for Grade: The most recent stock assessment suggests that the fishery is robust in all regions. Although regional catches slightly exceed the maximum sustainable yield (MSY), recent levels of spawning potential are well above the level that will support the MSY (Rice et al. 2014/SPC Stock Assessment).

Longline Bycatch (includes non-desirable tuna)	2010-2014: Average 790 mt/yr (Range: 552-1253 mt/yr). (Calculated from Gillet 2016)	No Clear Trend	Fair

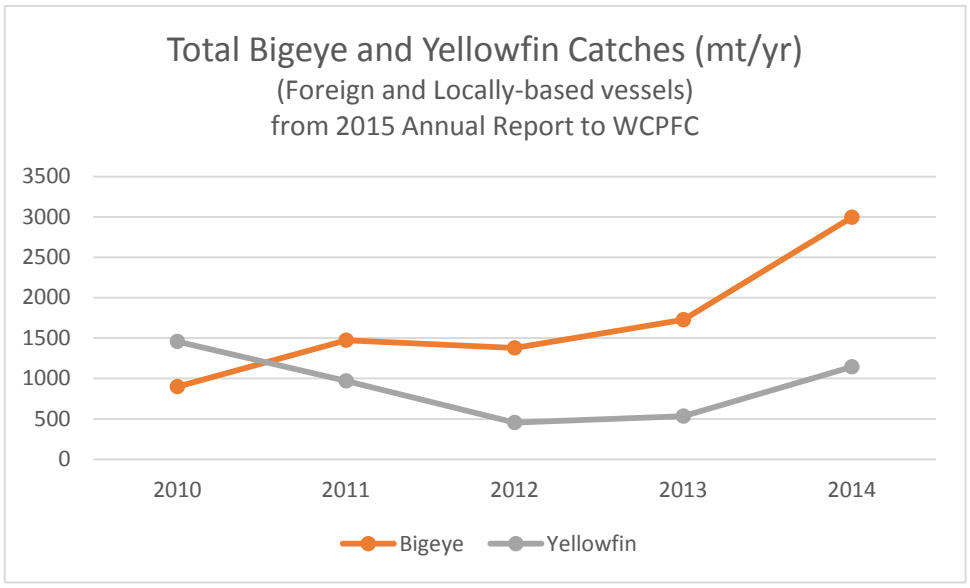
Basis for Grade: Subjective. Palau's average bycatch is around 20% of total catch, similar to global tuna fishery average (International Seafood Sustainability Foundation 2017).

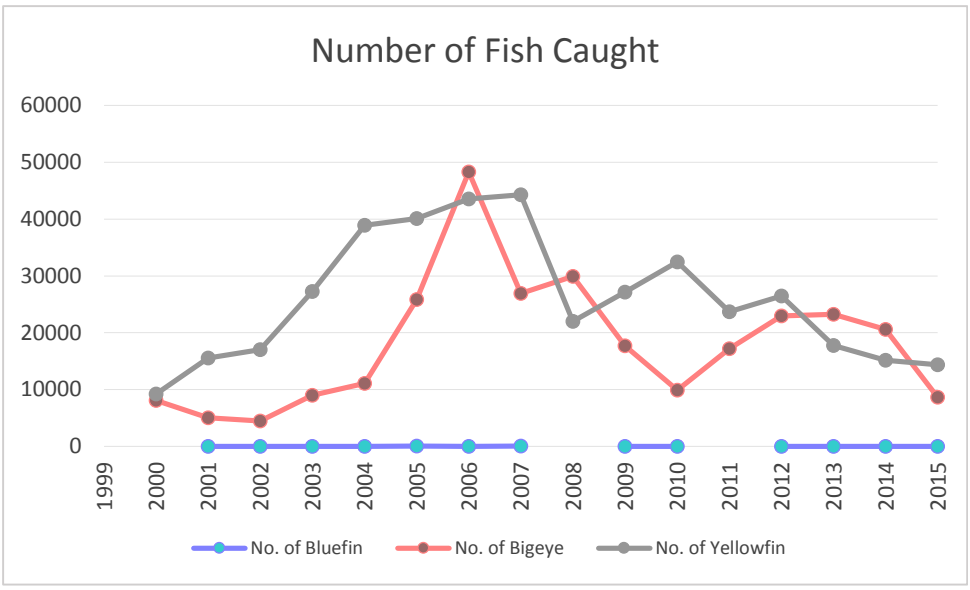
Local artisanal offshore fishery catch	2016: Around 100 mt/yr (Ann Singeo/Ebiil Society 2017, unpublished; Gillet 2016)	No Clear Trend	Poor

Basis for Grade: Subjective. Far below capacity. Majority of catch goes to restaurants (see next indicator) and does not contribute to local food security.

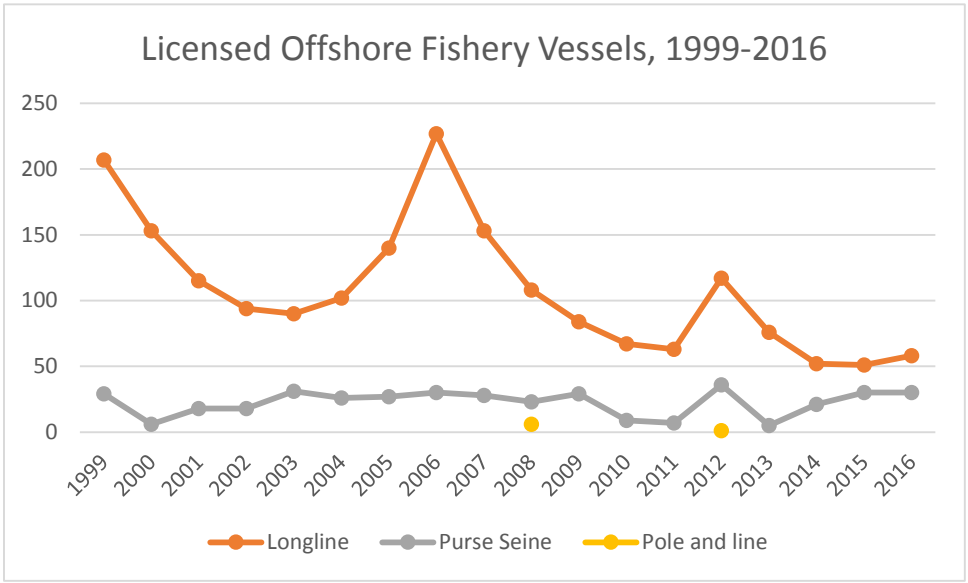
Tuna Fish going to restaurants	2016: 94 mt/yr (Ann Singeo/Ebiil Society 2017, unpublished)	Increasing	Fair

Basis for Grade: Subjective. Desirable trend, but still far under capacity.





When caught, number of bluefin ranged from 1 to 17 fish.



Pressures and Unmitigated Risks

Pressures on offshore fisheries come from external forces, such as foreign demand, poaching, and Climate Change. Enforcement of the Palau National Marine Sanctuary will mitigate these risks.

There is no estimate of local Maximum Sustainable Yield (MSY) within the 20% Domestic Fishing Zone. This is critical to setting local, reduced fishery targets to sustain local food security needs.

In 2014 around 9% of households participated in offshore fishing (calculated from the 2014 HIES), whether part-time or full-time. This number is expected to increase significantly with support from the PNMS. As with reef fisheries, there is no monitoring of local fish harvest (either reef or offshore).

Monitoring Programs and Gaps

Offshore fisheries are well monitored. There are gaps in terms of local use of offshore fisheries, and bycatch is estimated.

Data is shared with the Western and Central Pacific Fisheries Commission (WCPFC) and the Secretariat of the Pacific Community (SPC). Data and reports are available online through their websites.

Select Marine Sites & Species

Summary and Major Points

Many species and sites are in poor condition
Where known, select species and sites have trends and grades that are negative and Poor, respectively. These can be attributed to direct mortality and overuse.

Species monitoring is a major gap
None of Palau's endangered non-fish and non-bird species are monitored by any regular, government-supported programs. Aside from passing laws and regulations, few agencies have any direct roles in managing these species and sites on a day-to-day basis. Reporting on existing conditions relies on State governments and/or nongovernment organizations.

Researchers have identified that Palau has a diverse Marine Mammal population, with as many as 30 whale and dolphin species residing in or passing through Palau's waters. Baseline data was collected in 2012.

Indicator	State	Trend	Grade
Mastigias Jellyfish in Ongeim'l Tketau	2016: Appeared to disappear (estimated at 600,000) (Howard 2016/National Geographic Article)	Declining	Poor

Notes on trend: From 1998-2008, population of Mastigias varied from 5 to 25 million; averaging 12 million (Colin 2009). Following disappearance in 1998, it wasn't until early 2001 that populations neared typical levels.

Basis for Grade: Subjective, due to population crash. Note natural variability.

Number of Marine Lakes Protected	57 closed Marine Lakes in Palau (3 in Airai, 1 in Peleliu, 53 in Koror); 56 fully protected from visitors and the remaining one regulated; Only more isolated lakes have jellyfish (Colin 2009).	Good

Basis for Grade: Subjective. Desired protection threshold to ensure the long-term viability of the conservation target= 100%, based on TNC ERA (2007). Each lake has endemism and unique features both spatially and over time (Koror State 2012/World Heritage Nomination Dossier). Despite regulation, there have been observed impacts from visitors to Ongeim'l Tketau (sunscreen residue and invasive species).

Indicator	State	Trend	Grade
Extent of Aiptasia (Non-native sea anemone in Ongeim'l Tketau)	2006: Aiptasia colonies covered shallow bottoms and roots almost all the way around the lake (Patris et al. 2011)	Increasing	Poor

Notes on trend: Small patches identified only near the visitor dock in 2003.

Basis for Grade: Subjective. Rapid spread. Impact on native species unknown (Patris et al. 2011) and no known measures to counter the invasion (Marino et al. 2008).

Marine Invasives	2016: Port surveys identified 4 potential pests (Campbell et al. 2016)	Increasing	Fair

Notes on trend: In 2008, only one marine invasive species had the potential for becoming a "pest" organism in Palau, and the hydroid, *Eudendrium carneum.* (Marino et al. 2008).

Basis for Grade: Undesirable trend and 4-fold increase in 8 years; however in Palau there are still only few of the 33 known marine invaders in the Micronesia Region (Ruiz and Zabin, eds 2014). Palau has "High" risk of invasions from 31 marine invaders and "Medium" risk from another 108 invaders.

Dugongs	5 to 15 Dugongs killed for food per year (3 to 8% of the population). Total population unknown, "a few hundred." (CRRF 2012)	Unknown Decreasing or Stable	Poor (mortality = 8%) or Fair (mortality = 3%)

Basis for Grade: Even without human-caused mortality, maximum population growth rate would be no more than 5%. Impacts of mortality felt even more so in small populations. If mortality is 3%, population may be stable but still at risk due to small size and isolation. Higher mortality would suggest a declining population.

Macro-invertebrates/ Clams	2010-2014: Macro-invertenrates decreased in outer reef habitats, driven by decrease in clams (Gouezo 2017, PICRC Monitoring Report, unpublished)	Declining	No Grade Assigned No standards or goals on which to base grade

Learning more about marine sites and species/ Monitoring Programs and Gaps

Beyond responding to violations (the Division of Fish and Wildlife), there are no clear authorities in the National Government to address management concerns over species and sites.

CRRF is the country's foremost authority on marine lakes and on the *Mastigias* jellyfish. Marine lakes fall under the jurisdiction of individual states. CRRF partners with Koror State.

The Biosecurity Office has the authority to monitor and react to marine invasives.

Sea Turtle Monitoring occurs on an ad hoc basis, usually by nongovernmental organizations like Ebiil Society and PCS. There is no current estimate of sea turtle population and no ongoing programs exist. Dugongs are monitored by CRRF and private partners.

There is currently no regular monitoring of dive sites or the dive experience, although this has been the subject of research at PICRC and Koror State. The Bureau of Tourism could have the authority to monitor and manage these sites.

Indicator	State	Trend	Grade
Sea Turtles	2014-2015: • 60% of nests poached (Rock Islands) • Evidence of eggs spoiled by seawater and loss of nests due to typhoons (impacts of Climate Change). • 243 nests discovered; 50% showed no recent nesting activity. (Kitalong 2016) 2016: • 17% poached (Ngerkeklau and Ngerchur, Ngarchelong) (Ebiil Society 2016).	Increasing *Notes on trend:* 1991-1992: 44% of nests poached; 2005: 36% of nests poached (Kitalong and Eberdong 2005 in Kitalong 2016). Perceived trends: Population size: Declining; Population Density: Declining; Average size of individual turtles: Declining; Levels of nesting: Declining; in (Guilbeaux and PCS 2001). Possible decrease in total nesting activity on Kmekumer (6 nests in 2015-2016; 8-9 nests in 1991-92 and 2005); possible increase in total nesting activity on Ulong (13 nests in 2015-2016; 6 nests in 2005) (Kitalong 2016). No data on population. *Basis for Grade:* Subjective, based on low population starting point and declining trend. High level of poaching despite protections and evident sales of sea turtle products in 2017 despite moratorium. "Gradual but steady decline of [hawksbill] abundance" between 1949-1978; and "fishermen seem unanimous in their opinion that turtles are far less abundant today than they were 10-20 years ago with a decrease in the numbers of large green turtles especially noticeable" (Eckert 1993/NOAA). "Anecdotal information and observations over recent decades point to marked turtle population decline and to simultaneous increases in local harvest in Palau;" Estimated maximum of 60 Hawksbill Turtles nesting each year and 125 Green Turtles nesting each year (Guilbeaux and PCS 2001).	Poor
Snorkel and Dive Sites	2015: (Otto et al. 2015) • There was significantly higher rubble coverage at the sites that tourists visit compared to the non-visit sites • There was significantly higher coral fragmentation at visited sites compared to non-visit sites • The destruction of shallow coral reef communities due to high visitor numbers was observed during surveys. 2010: (Poonian et al. 2010) • 66% of Guides concerned about diver congestion at German Channel. Estimated 50,000 dives at German Channel/year. • Estimated 589,000 coral contacts and 400 coral breakages annually at German Channel (from divers). • Divers wearing gloves touched hard coral more often than those not wearing gloves, and divers using cameras touched hard coral more often than those not using cameras. • All guides were observed deliberately keeping away from the substratum, although few paid attention to coral contacts by clients.		Poor *Basis for Grade*: 2010 visitation rates far exceeded the 4,000–7,000 dives per year per site considered to be a reliable rule of thumb to estimate carrying capacity for scuba divers (in Poonian et al. 2010). The number of tourists has increased since 2010, indicating even more negative impacts.

Pressures and Unmitigated Risks

One of the primary risks facing these marine species and sites is the lack of knowledge about their state and extent. Management is entirely ad hoc, based on projects, or falls under the purview of state governments.

Overuse and direct human-caused mortality are the main pressures on these sites and species, and are generally unmitigated. Regulations exist but are minimally enforced. There are gaps in leadership, especially as the authority over sites and species is unclear, with some at the national level and some at the state level. Demand for regulated species comes from all sectors of society, including leadership.

Seagrass and Invertebrates

Summary and Major Points

Sea Cucumbers are in Fair to Good condition

The commercial export moratorium put in place in the 1990s appears to be protecting most sea cucumbers, although some loopholes exist. Cucumber populations in highly populated areas (Koror and Airai) have declined.

Macro-invertebrate population and seagrass fish biomass are low

Commercially-targeted macroinvertebrate populations are very low. Fish abundance and biomass declined in seagrass habitats through time. Fish biomass in unprotected seagrass habitats is very low.

Indicator	State	Trend
Seagrass cover	• Percent cover declined in all sites (4 MPAs and associated reference sites) between 2011 and 2015 • 2 sites (both the MPA and its reference) started to increase seagrass cover after 2013. (Mereb et al. 2016)	No Clear Trend
Seagrass: Fish biomass and abundance	• Fish biomass declined between 2011 and 2015 in all sites (MPAs and reference sites) • MPAs have significantly higher biomass (Mereb 2016) • Fish abundance declined between 2011 and 2014 (See Figures p. 38). (Gouezo 2017, PICRC Monitoring Report, unpublished)	Declining
Seagrass: Macro-invertebrate density (sea cucumbers, clams, urchins, trochus)	• Low macro-invertebrate density across all sites (MPAs and reference) from 2011-2015 (0.7 to 4.5 invertebrates per 100 square meters) • Density remained low over the years surveyed. (Mereb 2016)	Declining

Indicator	State	Grade
Molech (*Holothuria scabra*)	2009: • Overexploited in Airai, relatively good abundance in Ngarchelong and Ngatpang (but smaller) • Not reaching larger/mature sizes. • Increasing use by subsistence fishery, fishery impact no longer "moderate," but growing. (Pakoa et al. 2009) • 80% decline in harvest rates, 1991-2008 (Kitalong 2008-b)	Fair
Basis for Grade: Populations good in areas where not heavily fished; but highly preferred species and fishers are moving to new locations. Inadequate protection of breeding stocks in Airai. "The common view that subsistence fishing of *H. scabra* is modest and cannot deplete the resource ... is no longer a valid view" (p. 29) (Pakoa et al. 2009).		
Ngimes (*Stichopus vastus*)	2009: • Stocks in good condition (Pakoa et al. 2009)	Good
Basis for Grade: "*Stichopus vastus* is the most densely populated resource in Palau with wider distribution" (p. 29), Pakoa et al. (2009). Cutting can result in mortality due to infection and stress (Kitalong 2008-b).		
Cherumrum (*Actinopygra* sp.)	2009: • Stocks in Koror and Airai depleted • Ngatpang and Ngarchelong have stable populations with larger individuals (Pakoa et al. 2009)	Fair
Basis for Grade: "Third most abundant resource with wider distribution as *S. vastus*." Note overharvesting and need for tighter management (Pakoa et al. 2009).		
Sea Cucumbers in Ngatpang MPA	2009: • Good aggregation observed in the MPA • Few big animals, which suggests poaching (Pakoa et al. 2009)	Good
Basis for Grade: "The marine protected area at Ngatpang has been effective at conserving *H. scabra,*" with some need to increase monitoring (Pakoa et al. 2009).		

Pressures and Unmitigated Risks

Pressures in seagrass beds come from sedimentation and direct use. Although commercial harvest is banned, loopholes have in the past allowed for overharvest (Pakoa et al. 2009). Some macro-invertebrates may be resilient to Climate Change and thus could be targeted for habitat restoration purposes. Land use and sedimentation is a generally unmitigated pressure across Palau.

Learning more about seagrass and invertebrates / Monitoring Programs

PICRC added seagrass beds to its long-term Coral Reef Monitoring Program in 2011. Seagrass beds fall under the jurisdiction of states. BMR tracks exports (2015 export: 35,000 invertebrate pieces).

Mangroves

Summary and Major Points

Baseline information is good, but historical information is conflicting

Determining change in mangroves over time is difficult because historical information was collected using many different resolutions and methods. Palau has a very comprehensive Mangrove Management Plan (Metz 2000) which established a "No Net Loss" Policy. It includes a thorough action plan and baseline information. Baseline data on species distribution also exists from extensive surveys in 2007. PALARIS has the ability to track change in mangrove extent over time.

Mangrove extent has increased, but with complex impacts

Mangroves are extremely valuable habitats, but their role in a bigger estuary—and the impacts of their growth on the seaward side into Airai Bay— is unclear. They reduce sedimentation, but displace seagrass.

Pressures and Unmitigated Risks

Mangroves face pressure from both terrestrial and marine environments, facing sedimentation from the landward side and sea level rise from the ocean side. Direct human conversion of mangrove into filled land is the major unmitigated threat, and there are few regulations in place to slow the current pace of conversion.

Learning more about mangroves

PICRC has some data on mangroves, as do private businesses like The Environment Inc. There is no government agency with the mandate to track mangroves. Through periodic land cover maps, PALARIS has been able to track mangrove over time.

States have the authority to lease mangroves and permitting authority falls under EQPB.

Monitoring Programs and Gaps

There appears to be no agency tasked with monitoring every aspect of mangroves (from forest to seafloor), and thus, there are no regular mangrove management or monitoring programs, despite the Mangrove Management Plan. This is a major gap.

Indicator	State	Trend	Grade
Extent of mangroves/	2014: 50 km^2 (PALARIS 2017, unpublished / WorldView-2 imagery)	**Increasing** (Nationwide)	**Fair**
Rate of change of mangroves	• Loss of 0.04 km^2/yr (9.8 acres/year); reclaimed for development (outside Airai Bay) • Airai Bay: Gain of 0.1 km^2/yr (24 acres/yr) (Neville 2014)	**Increasing** (Airai Bay) **Decreasing** (Outside Airai Bay)	*Basis for Grade:* The Palau Mangrove Management Plan (Metz 2000) listed "Future Desired Conditions." Some of these have been met, including increased distribution of mangrove and adherence to a "No Net Loss Policy." Many conditions have not been met, such as specific mangrove land use policies and regulations.

Notes on trend: Nationwide the extent of mangroves has increased. In 2011 there were 48 km^2 of mangrove nationwide (Kitalong 2010/SWARS) and in 2001 there were 46 km^2 of mangrove (PALARIS 2017, unpublished IKONOS/NOAA data). However, these measures were made using different methodologies: the 2001 value was derived from IKONOS Satellite imagery using 1-hectare resolution and the 2014 WorldView-2 imagery used a 5-meter resolution (PALARIS 2017, unpublished). Older measurements of mangrove included very different measurements from the 1980s: 40.25 km^2 (Cole et al. 1987 in Colin 2009) and 47.08 km^2 in 1985 (Wilkie and Fortuna 2003) and similarly different measurements from the 1990s: 38 km^2 (1994 SOE) and 45 km^2 (Maragos et al. 1994). Neville (2014) found that mangrove extent is expanding in Airai Bay, but that mangroves are being lost outside of Airai Bay for development.

1.7 km^2 of mangrove was lost between 1968 and 2007 for development, roads, landfill, and aquaculture, mostly on Babeldaob (Kitalong 2010/SWARS). There has been a clear increase in mangrove extent in Airai: 3.7 km^2 gained (calculated from Kitalong 2010/SWARS). Mangroves increased in Airai Bay between 1946 and 2000 on the bay side, possibly due to sedimentation (Colin 2009). The impact of increasing mangrove extent in Airai is unknown, as mangroves may have displaced some seagrass habitats, with unknown impact.

Total mangroves protected	2015: 19.7 km^2 (40% of total); 11 Protected Areas with some or all mangrove. (Calculated from PCS Protected Area Scorecard 2015; version updated with assistance from TNC). Mangroves trapped about 30% of riverine sediment in the Ngerikiil and Ngerdorch; mangroves comprised only 3.8% of each catchment area (Victor et al. 2004).	**Fair** (55% of way to Management Plan goal)
Mangroves with human impact	2007: 100% of states (14 surveyed) had mangroves showing strong impact from human activities (cutting, sedimentation, erosion, and filling) (Mersai 2007)	**No Grade Assigned** No standards or goals on which to base grade

Basis for Grade: Comparing current to desired, based on protection goals determined in Metz (2000). Metz (2000) identified 35 km^2 (75% of mangroves) for protection. Very Good = Current is at least 90% of desired. Good = 75-90%. Fair = 50-75%. Poor =<50%.

Palau has a Mangrove Management Plan (Metz 2000). A baseline survey was conducted in 2007 (Mersai 2007, unpublished/PICRC) to determine species distribution and condition. 110 study sites were surveyed in 14 states to determine/confirm Palau's mangrove species list (18) and to map their location and condition (including % cover, sociability/relationship to other plants, and species composition).

Abundant Mangrove Species

2007: Six species were abundant and found in healthy populations:

- *Rhizophora apiculata* (Bngaol)
- *Rhizophora mucronata* (Tebechel)
- *Sonneratia alba* (Urur)
- *Xylocarpus granatum* (Meduulokebong)
- *Nypa fruticans* (Toechel)
- *Ceriops tagal* (Biut).

(Mersai 2007)

Rare Mangrove Species

- *Avicennia alba* (one area in Ngaraard)
- *Xylocarpus moluccensis* (three locations)
- *Sonneratia caseolaris* (Rock Islands)
- *Rhizophora stylosa* (Peleliu and Ngerchelong)
- *Lumnitzera littorea* (Mekekad)
- *Excoecaria agallocha*
- *Heritiera littoralis* (Chebicheb)
- *Acrosticum speciosum* (Okuam)
- *Xylocarpus caseolaris* (possibly Meduulokebong)

Forests

Summary and Major Points

Total forest extent is good

Forest extent on Babeldaob has increased since the 1940s, when significant swaths of land were cleared for agriculture and mining. While recovery appears to have slowed, forests continue to expand. Even secondary forests harbor biodiversity. Forest extent in outer islands is decreasing.

Quality of forest habitat is declining

Of utmost concern is burning, which destroys forest and degrades land and water. The rate and extent of burning has increased dramatically in recent years. Forests are also showing signs of damage and degradation, especially from invasive vines.

Insufficient forest and terrestrial land is protected and there is little detailed habitat information

Forests are protected at levels far below their conservation thresholds and below national and regional goals. There is inadequate information available to assess the true amount of each type of habitat that is protected.

Indicator	State	Trend	Grade
Change in Forest—Babeldaob and Koror, Peleliu, and Angaur	• Increasing forest extent in Babeldaob • Decreasing forest extent in Koror, Peleliu, and Angaur (Kitalong 2008-a)	**Increasing** (Babeldaob) **Decreasing** (Koror, Peleliu, & Angaur)	**Good** **Fair**

Notes on trend: 2007: Forested land in Babeldaob was maturing and may be encroaching on non-forest vegetation. Peleliu, Koror, and Angaur were losing forested land to urban and non-forest vegetation land uses (Kitalong 2008-a). Note there was relatively slow growth in recent years in southeastern Babeldaob (Kitalong 2008-a).

Basis for Grade: Subjective, based on different impacts. Increasing forest on Babeldaob reduces threats from sedimentation and provides habitat for biodiversity. Forest loss in Koror, Peleliu, and Angaur negatively impacts biodiversity, but does not have the same far-reaching and long-lasting impacts on marine habitats that loss of forest on Babeldaob does.

Indicator	State	Trend	Grade
Total area of Forest, Nationwide	2007: 82% of total land (~400 km^2) (Donnegan 2007 in Kitalong 2008)	**Stable or Increasing**	**Good**

Notes on trend: In 1987 80% of Palau was forested (~390 km^2) (Cole et al. 1987 in Kitalong 2008-a). Note that imagery and methods were not the same between 1987 and 2007 measurements. There is disagreement over whether Palau was once 100% forested or if savannas are native/natural habitats.

Basis for Grade: This value used as a proxy: 30% Forest Loss appears to be a threshold for biodiversity maintenance; biodiversity declines with additional loss (Estavillo et al. 2013).

Indicator	State	Trend	Grade
Change in Landcover, Ngardok Nature Reserve	2006: • 72.9% Forest Cover • 23.5% Savanna (Dendy 2011)	**Increasing (Forest cover)** **Declining (Savanna)**	**Good**

Notes on trend: Forest: 69.3% (1976); 58.6% (1947). Savanna: 27.1% (1976); 37.3% (1947) (Dendy 2011).

Basis for Grade: Desired trend. Note: Recovery almost 10 times faster in Ngardok than in Ngeremeduu, possibly due to fire control within the Ngardok Nature Reserve for the last 15 years (Dendy 2011).

Indicator	Total terrestrial habitat protected[6]	Total terrestrial habitat in PAN	Total Babeldaob land protected
State	2015: • 90 km^2 • 20% total land (mangroves excluded); • Much in RISL (Calculated from PCS Protected Area Scorecard; 2015 version updated with assistance from TNC).	2015: • 39 km^2 in PAN • 9% of total land (2015 PAN Report)	2015: • 33.8 km^2 of Babeldaob • 10% of island (Calculated from PCS Protected Area Scorecard; 2015 version updated with assistance from TNC).
Grade	**Poor** (43% of way to ERA goal) Desired protection threshold = **An average of 46%**[7]	**Poor** (45% of way to MC goal) Micronesia Challenge (MC) Protection Goal = 20%.	**Poor** (Average 22% to ERA goal) Desired protection threshold = **An average of 46%**[7]

[6] Protected Areas are generally listed as "marine, mangrove, or terrestrial" and thus it is difficult to determine the exact area of specific habitats protected within them. The Nature Conservancy's Ecoregional Assessment (TNC ERA 2007) lists 18 specific terrestrial habitat types. These are collapsed here and desired thresholds are averaged.

[7] Protection thresholds vary by land type, but for most targets (except degraded forest), at least 30% of terrestrial targets should be protected to ensure the long-term viability of the conservation target, based on TNC ERA (2007). Thresholds for specific habitats range from 30% to 90%. Doing a weighted average across targets, approximately 46% of terrestrial areas should be protected. Note that the Aichi Target (17%) and the Micronesia Challenge Target (20%) are based on "Effective Conservation," not solely on square area protected.

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) or the Micronesia Challenge goal. Very Good = Current is at least 90% of threshold. Good = 75-90%. Fair = 50-75%. Poor =<50%.

Indicator	State	Trend	Grade
Trees with Damage in Crown	2014: • 20% of trees with damage in crown.[8] (Calculated from 2014 Forest Inventory and Analysis (FIA) Data Queries (Area by Disturbance))	Increasing	Fair

[8] Most prevalent damage type was "Conks, fruiting bodies, and advanced decay" followed by "Vines in the crown" and "Loss of apical dominance/dead terminal" (FIA Data 2014).

Notes on trend: 2003: 13% of trees had damage of some kind (USDA Forest Service 2016). Growth of damaging vines in crowns was most prevalent damage type, with conks and lost apical dominance following in prevalence. The most frequently identified damaging agents were other vegetation, disease, and weather (Queried from FIA data 2003).

Basis for Grade: Increase in percent of trees with damage from 2003 to 2014 of more than 50% from 2003 value.

Disturbed Forest Land	2014: • 125 km^2 (31,000 acres) • 25% of total land area (all possible disturbances, not limited to clearing). (Calculated from 2014 Forest Inventory and Analysis (FIA) Data Queries (Area by Disturbance))	Increasing	Good

Notes on trend: Similar query not possible with 2003 FIA data; but invasive vines and fire are known to have increased.

Basis for Grade: This value used as a proxy: 30% Forest Loss appears to be a threshold for biodiversity maintenance; biodiversity declines with additional loss (Estavillo et al. 2013). Good: Disturbed rate below threshold. Fair: Disturbed rate at or near threshold. Poor: Disturbed rate above threshold.

Bare area of Ngerdorch Watershed	• 55 acres of land • 6 km = length of riparian area needing restoration (Calculated from 0.5% of total watershed area (44.2 km^2) given in Kitalong 2010/SWARS; and by estimating using maps of watershed)	Increasing	Fair

Basis for Grade: Subjective. Amount of bare area is relatively less than in the Ngerikiil Watershed, and thus impacts are fewer. It is a large amount of bare area. Rehabilitating this area would require 55,000 trees at 1000 trees per acre. (Compare: in 2005 the Division of Forestry with assistance from the US Forest Service distributed 4600 seedlings of native trees (Brel and Beck 2006)).

Volume of Forest	2014: 278 million cubic ft (Calculated from 2014 Forest Inventory and Analysis (FIA) Data Queries (Area by Disturbance)) 2007: 192 m^3/hectare (Kitalong 2008-a)	No Clear Trend	No Grade Assigned No standards or goals on which to base grade

Notes on trend: Varies based on data source and time period analyzed: Decreasing: 2003: 315 million cubic feet (Calculated from 2003 FIA Data). Increasing: 1988: 122 m^3/hectare (Kitalong 2008-a).

Basis for Grade: Increase from 1988-2007 possibly due to thinning and maturation of trees (Kitalong 2008-a).

Indicator	State	Trend	Grade
Fire	2015: • Annually, average of 1.5% of Babeldaob burned • In 2015, 507 hectares (5 km^2) burned on Babeldaob (1.54% of island) in 179 fires (BWA 2016) 2012: Fires on 100% of conservation areas/yr (GEF5 ProDoc 2015) Top causes of fire: • Arson (31%) • Clearing by hunters (23%) • Farmers (21%) (Kitalong 2010/SWARS)	**Increasing** *Notes on trend:* 2007-2009: Total of 7 hectares burned (0.02% of island) from 68 fires (Kitalong 2010/SWARS). *Basis for Grade:* Subjective. 500 hectares/1.5% of Babeldaob is a discernably large percentage of the island. Significantly large increase in fires from 2007 to 2015 is dramatic and unsustainable.	**Poor**
Nursery / Planting volume	2006: Distributed 4,551 seedlings of native and fruit trees to interested local farmers and individuals (Brel and Beck 2006)	**Unknown**	**No Grade Assigned** No standards or goals on which to base grade

Pressures and Unmitigated Risks

Primary pressures on forests and terrestrial lands come from clearing for development, farming, and from fires (most of which are set purposefully). There is little legal authority over fires on Babeldaob, and risks from fire are generally unmitigated, despite investment in a Fire Station on the island. Forest disturbance, primarily from invasive vines, is another unmitigated risk.

Learning more about forests and terrestrial land

The Division of Forestry has a clear mandate to manage and monitor forests. The Division partners with the US Forestry Service on monitoring and research. Bare land also falls under the purview of the Bureau of Agriculture. Fire is managed by the Ministry of Justice Division of Fire and Rescue. Fire also falls under the Biosecurity Office under MNRET.

Many private businesses and individuals are also authorities on Palau's forests, notably The Environment Inc. (Ann Kitalong) and Palauan Made (Tarita Holm).

Management of terrestrial protected areas and forests falls to States, with some assistance from PAN and nongovernmental organizations.

Monitoring Programs and Gaps

Forests are inventoried every decade using the Forest Inventory and Analysis (FIA) protocol. Data are publicly available although analyses are not. There is a gap in monitoring protected areas by habitat type, both inside and outside the PAN. There is inadequate fire monitoring (including extent of burn), which is another major gap.

Birds

Summary and Major Points

Belochel are on a clear path to extinction

The population of Belochel has dropped dramatically since 1991, from 13,700 to 3,000. Without immediate intervention, this cultural icon of Palau will become locally extinct.

Many bird populations are declining

Many of Palau's endemic species declined between 1991 and 2005. There has been a steady increase in the number of birds on the IUCN Red List of Threatened Species.

Birds are monitored well, but improvement in reporting and the use of the data would help

The Belau National Museum publishes an annual State of the Birds Report. It focuses on new research findings and "hot topics," although the program does track key indicators. The last full National Bird Survey was conducted in 2005.

Bird diversity is good in most locations

The number of bird species is still above Palau-specific thresholds for healthy/expected diversity.

Indicator	State	Trend	Grade
Bird Diversity	2010-2014: Long Island Park (Koror): Average = 15 native resident species (Estimated from Figure 2, BNM 2014/State of Birds) 2011-2015: Rock Islands (Koror): 35 native resident species (Olsen et al. 2016) 2009-2013 (native resident species): Ngardok: Average = 12.4 species Ngermeskang: 13 species Ngerderar: 10+ species Mesekelat: 10+ species "Taki" Waterfall: ~9 species Ngatpang Reference Station: 10 species Ngiwal Reference Station: 10+ species (BNM 2015, unpublished report to PAN)	**Stable** (Ngardok: Slight Decline) *Notes on trend:* Graphs in BNM (2015, unpublished report to PAN) show most locations with long-term stability.	**Good** (Taki just below threshold) *Basis for Grade*: Specific threshold for Palau: Minimum of 10 species as the minimally acceptable threshold for diversity (BNM 2014/State of Birds).

Indicator	State	Trend	Grade
Population/ Abundance of Belochel (Micronesian Pigeon)	2014: 3000 (78% decline from 1991) (Olsen in BWA 2016) 2005: 0.75 birds/station (50% decline from 1991) (VanderWerf 2007)	Declining	Poor

Notes on trend: The decline has been clear over every survey: In 2005: 8,175 (40% decline from 1991) (Ketebengang and Gupta 2011). 1991: 13,718 (Engbring 1992). 1991: 1.5 birds per station. 2011: Micronesian Pigeon added to IUCN Red List (NT-Near Threatened) (IUCN Red List 2017). 2017: IUCN/ BirdLife International discussion period opened for potential uplisting to VU-Vulnerable due to estimated reduction of ≥30% over three generations (c.20 years in this species) (Birdlife 2017).

Basis for Grade: Severe decline. Note data collection was not standardized between various surveys.

Locations where Belochel observed	2010: 13 Sites (Ketebengang and Gupta 2011)	Declining	Poor

Notes on trend: 2005: 20 Sites (Decline of 35%) (Ketebengang and Gupta 2011).

Basis for Grade: Large decline.

Population/ Abundance of Biib (Fruit Dove)	Declines of 46 to 66% from 2010 to 2014 (Calculated from p.5 Figures in BNM 2015, unpublished report to PAN)	Declining	Poor

Notes on trend: Declining trends across 7 terrestrial monitoring stations (2010-2013), Ngardok (2010-2013), and Ngeremeskang (2010-2014). (BNM 2015, unpublished report to PAN).

Basis for Grade: Large decline.

Number of resident/ endemic birds on IUCN Red List of Endangered Species	2017: • 7 species (NT-Near Threatened or higher). • Palau Kingfisher (NT), and Palau Nightjar (NT) added since 2011. (IUCN Red List 2017)	Increasing	Poor

Notes on trend: 2011: 5 species on list: Micronesian Pigeon added (NT-Near Threatened). 2005: 4 species on list: Ground Dove (NT), Nicobar Pigeon (NT), Micronesian Megapode (EN-Endangered), Giant White-eye (NT).

Basis for Grade: Number of species on list has almost doubled since 2005.

Megapode Populations	2013: 2.69 birds/station, Kayangel main island (PCS 2017, unpublished Kayangel Biodiversity Monitoring Data) 2011-2015: Major nesting grounds documented; 86% of nesting mounds in a limited number of low-lying coastal nesting grounds in the Rock Islands and Kayangel; Megapode counts exceed those from prior surveys, but from more survey sites. (Olsen et al. 2016)	Increasing	Poor

Notes on trend: 2013: Increase on **Kayangel** main island after 2011 rodent eradication. 2010: 0.25 birds/station and 2011: 0.36 birds/st (pre-eradication); 2012: 0.51 birds/st and 2013: 2.69 birds/st (PCS 2017, unpublished Kayangel Biodiversity Monitoring Data). Unclear trend in **Rock Islands**: Megapodes detected in 60% of counts in 2011-2015 (140 counts over 10 island groups). 12% of counts were in same location as 2005 survey, which also detected megapodes in 12% of counts. Megapodes were detected in 23% of counts in 1991 (same locations) (Olsen et al. 2016).

Basis for Grade: Megapodes are globally endangered (EN). Forest canopy is important to nesting and nests were be disturbed by typhoons (Olsen et al. 2016); nesting areas are fragile. Poaching of eggs occurs.

Indicator	Species	Trend
Stable resident/ endemic bird species	1991 to 2005: 15 species • White-tailed Tropicbird • Micronesian Megapode • Black-naped Tern • Bridled Tern • Palau Ground Dove • Palau Swiftlet • Collared Kingfisher • Micronesian Kingfisher • Cicadabird • Palau Flycatcher • Palau Fantail • Palau Bush-Warbler • White-breasted Woodswallow • Blue-faced Parrotfinch • Giant White-Eye (VanderWerf 2007)	Stable
Increasing resident/ endemic bird species	1991 to 2005: 3 species • Micronesian Honeyeater • Nicobar Pigeon • Banded Rail (VanderWerf 2007)	Increasing
Declining resident/ endemic bird species	1991 to 2005: 10 species • Slaty-legged Crake • Brown Noddy • Black Noddy • White Tern • Palau Fruit Dove • Micronesian Pigeon • Morningbird • Micronesian Starling • Caroline Islands White-Eye • Dusky White-Eye (VanderWerf 2007)	Declining

Learning more about birds

The Belau National Museum is the clear authority on birds, and is mandated to monitor and report on the state of birds. The Division of Fish and Wildlife has authority to enforce bird regulations.

PCS also has current and past knowledge on birds. Additional nongovernment organizations such as Island Conservation and Ebiil Society have significant knowledge and data on birds for select locations, arising from projects. An online eBird database has a growing body of citizen-science observations of birds in Palau.

Pressures and Unmitigated Risks

The primary unmitigated pressure on birds, and particularly Belochel, is hunting (all of which is illegal). Hunting is driven by demand that comes from all sectors of society, including leadership. Enforcing existing national laws and bird regulations is both physically and politically difficult. Enforcement capacities in State Protected Areas are also inadequate. Innovative thinking is necessary in order to stem the declines in iconic species.

Monitoring Programs and Gaps

BNM conducts regular monitoring following strict protocols. However, the annual report that is produced does not track the same variables every year and focuses on new findings and "hot topics." This is a gap that can be easily filled with regular inclusion of indicators such as Belochel, Biib, IUCN-listed species, and general diversity.

Select Terrestrial Sites & Species

Summary and Major Points

Conditions of select species and sites vary
The wide variety of terrestrial sites and species means that there are no overarching trends.

Terrestrial species & sites are not well studied
Beyond birds and the Forest Inventory Analysis (FIA), terrestrial sites and species are studied on an ad hoc basis, often as part of projects and research projects.

Indicator	State	Trend	Grade
Number of threatened resident/ endemic plants	39% of endemic species with enough data to assess; 61% were "Data Deficient": • NT[9] - 5 species (4%) • VU - 3 species (2%) • EN - 2 species (1.5%) • CR - 2 species (1.5%) (Costion et al. 2009)	Unknown *Notes on trend:* No trend, as the list was just established. There is a gap in monitoring the status of many plants, especially rare ones.	No Grade Assigned No standards or goals on which to base grade
Population of Saltwater Crocodiles	2008: 500-750 animals (Brazaitis et al. 2008) 2003: 96% of interviewees had spotted a crocodile within a year, in all states between Ngarchelong and Angaur (Matthews 2003)	Increasing or Stable	Good

[9] Threat categories are listed in order of increasing threat. NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered.

Notes on trend: 2003: Estimated ~400; 85 to 93% of survey respondents said there were more crocodiles than 5, 10, and 50 years ago (Matthews 2003). 1991 population: Fewer than 150 in the wild (Messel and King 1991). 1981: As many as 1000 crocodiles shot (Messel and King 1991).

Basis for Grade: Messel and King (1991) estimated wild populations never exceeded 1500 individuals. Population has increased from near local extinction; currently 33 to 50% of highest historic population estimate.

Indicator	Important Bird Areas (IBA) protected	Key habitats in the PAN	PAN: Habitats underrepresented
State	2015: 114.6 km^2 (53% of IBAs) (Calculated from PCS Protected Area Scorecard; 2015 version updated with assistance from TNC, cross-referenced against Holm et al. 2008) Desired protection threshold = **80%** (TNC ERA 2007)	2015, in multiple PAN sites: • Forests, • Rivers, • Lakes, • Ponds, (2015 PAN Report)	2015, in single or no PAN sites (2015 PAN Report): • Beach strand (on volcanic and limestone substrates), • Raised coralline atoll, • Savanna, • Swamp forest, • Bird nesting and breeding locations (for endangered species or aggregations), • Limestone forest
Grade	Fair (66% of way to ERA goal)	Good	Poor

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). Very Good = Current is at least 90% of threshold. Good = 75-90%. Fair = 50-75%. Poor =<50%.

Pressures and Unmitigated Risks

Pressures on these varied indicators vary, as expected. Critical habitats like IBAs fall under state jurisdiction, but are determined by global programs. Protection of IBAs alone will not protect birds, which face pressures from illegal overhunting.

Plants face a variety of pressures, including loss of habitat and invasive species. The major unmitigated pressure is lack of knowledge. There has been little dedicated governmental effort to learn more about Palau's endangered plants; all efforts have been driven by individuals and foreign agencies.

Learning more about terrestrial sites and species

There is no clear authority or expert on these select terrestrial indicators. Much of the knowledge of these indicators is held by individuals (such as Joshua Eberdong, Tarita Holm, Ann Kitalong, Ron Leidich, and Craig Costion) or by nongovernmental organizations such as PCS and TNC.

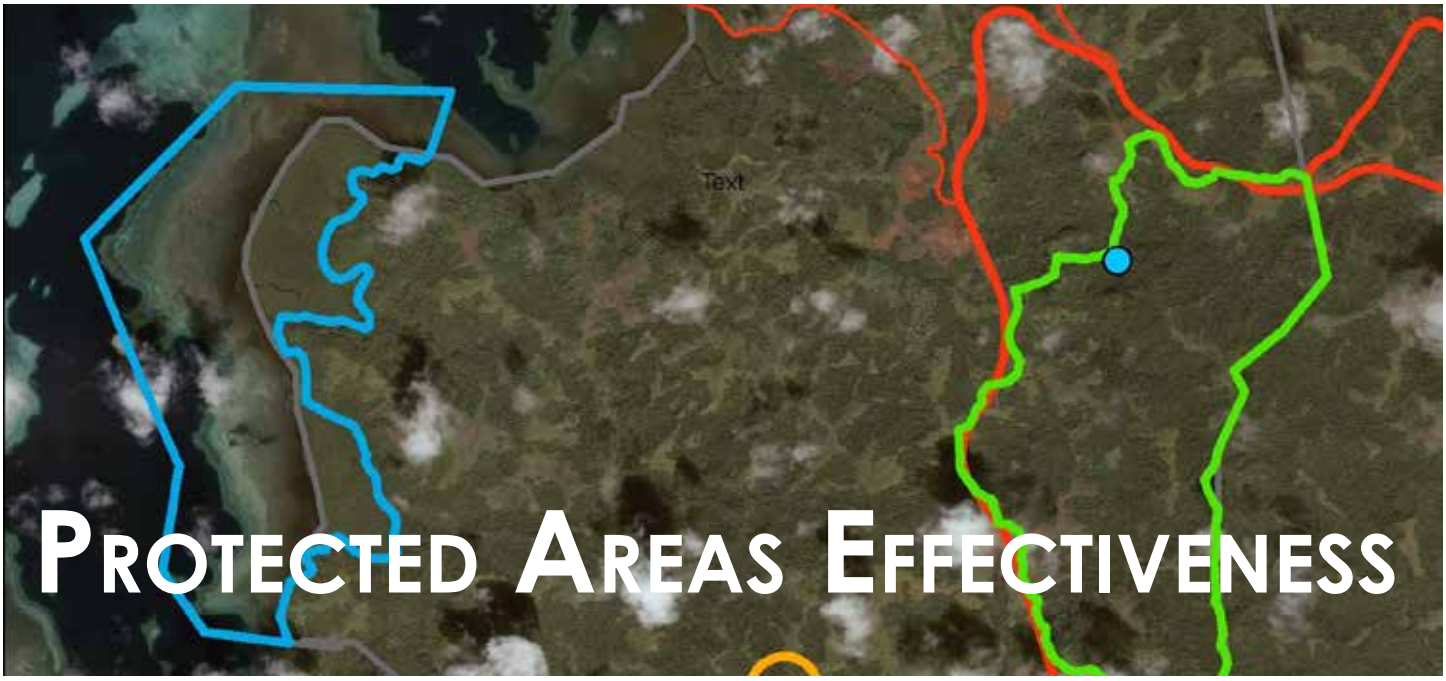
Fruit bats were surveyed as part of Palau's 2005 National Bird Survey, but this data was never analyzed and may be lost.

Monitoring Programs and Gaps

The Division of Forestry has authority over plants and endangered plant species, but gaps exist over plants that exist outside of forests, and conflicts arise over use of plants for purposes such as agriculture and landscaping. There is no agency that monitors terrestrial vegetation as a whole.

There are significant gaps in the monitoring of terrestrial animal species. Monitoring programs tend to be done by nongovernmental agencies or states based on project needs.

There is no government agency monitoring terrestrial protected areas outside of the PAN.



Protected Areas Effectiveness

Summary and Major Points

Protected areas are effective

Indicators such as biomass, number of fish, and ecological scores are higher in most PAs than in unprotected areas, and higher in areas that have been protected longer than those protected for less time.

Terrestrial protected areas lag behind MPAs

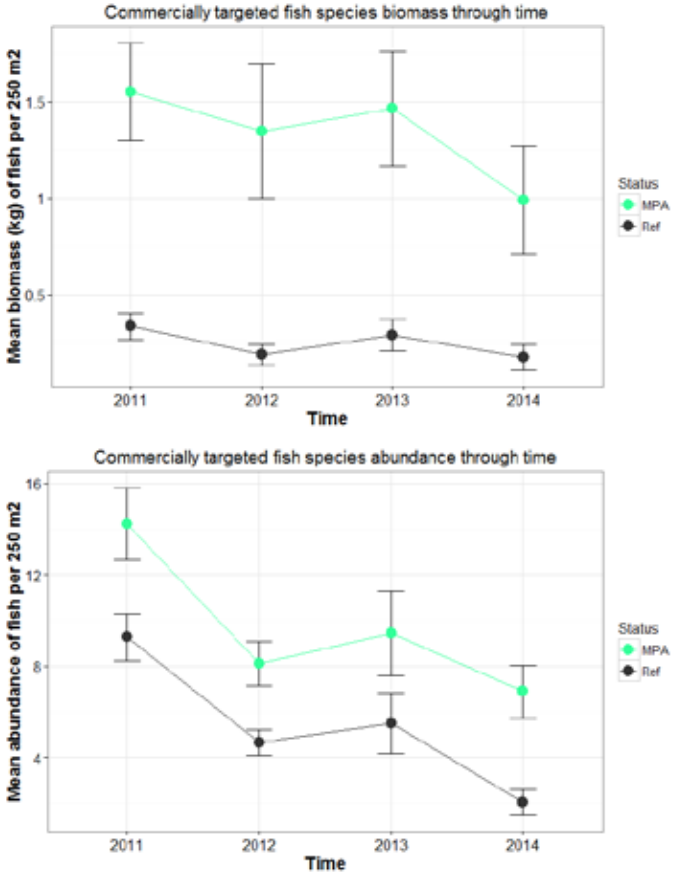
Much lower levels of investment into Terrestrial Protected Areas has led to their poorer performance. They have less available information, are fewer in number and extent, and have lower effectiveness scores.

Increased investment leads to improved results

Better effectiveness scores are associated with increased budgets and staffing.

Indicator	State	Grade
Ecological Scores of Marine PAs	• More than half of MPAs had a condition score of more than 50%. • 6 out of 9 (66%) Barrier Reef MPAs with ecological score of more than 50% • 5 out of 7 (71%) Inner Reef MPAs with ecological score of more than 50% • 4 out of 10 (40%) Seagrass MPAs with ecological score of more than 50% (Counted from graphs in Gouezo et al. 2016)	**Fair** (Average 60% sites with a condition score better than 50%) *Basis for Grade:* Based on average across sites. Very Good = 90% of sites above 50%. Good = 75-90%. Fair = 50-75%. Poor =<50%.
Ecological Scores of Terrestrial PAs	11 PAN Sites were evaluated for Management Effectiveness, including "Conservation Effect" (measures stable or improved biophysical targets): • 3 (27%) with "Good" rating • 1 (9%) with "Adequate" rating • 7 (64%) with "Poor" rating (2015 PAN Status Report)	**Fair** (Average across all sites is Adequate) *Basis for Grade:* Based on average across sites. Good = Average rating is Good. Fair = Average rating is Adequate. Poor = Average rating is Poor.

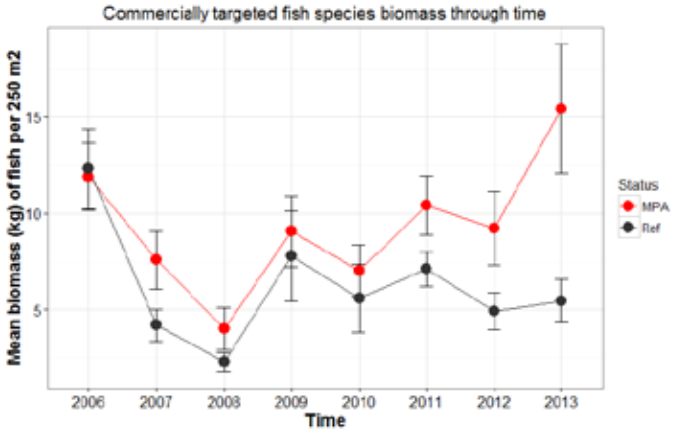
Indicator	State	Grade
Effectiveness of Terrestrial Protected Areas (PAN Sites)	• Ngemai: Increase in waterbird/shorebirds • PAN Sites exhibited a modestly higher bird species diversity than in other sites. • Both species diversity and indicator bird populations have declined inside some PAN Sites. (BNM data used in 2015 PAN Status Report)	Fair *Basis for Grade:* Subjective, based on desirable trend. Conditions for Terrestrial PAs in 2015 PAN Status Report were Poor to Adequate.
Compliance and Enforcement in PAN Sites	100% of sites assessed reported some decrease in illegal and/or destructive activities (2015 PAN Status Report)	Fair *Basis for Grade:* Subjective, based on desirable trend. Not rated Good because overall Enforcement in 2015 PAN Status Report was Poor.
Seagrass MPAs (Fish abundance, biomass, sea cucumbers)	2014: Fish abundance and biomass higher in Seagrass MPAs than unprotected sites; Declining trend for fish and biomass in seagrass MPAs (See Figures below). (Gouezo 2017, PICRC Monitoring Report, unpublished) 2009: Few large Sea Cucumbers in Ngatpang MPA, suggesting poaching (Pakoa et al. 2009)	Fair *Basis for Grade:* Subjective. Higher values than unprotected sites, but undesirable trend and possible poaching.



Top: Change in commercially-targeted fish species and protected species biomass (±SE) within seagrass beds and references sites through time. Bottom: Change in commercially-targeted fish species and protected species abundance (±SE) within seagrass beds and references sites through time (Gouezo 2017, PICRC Monitoring Report, unpublished).

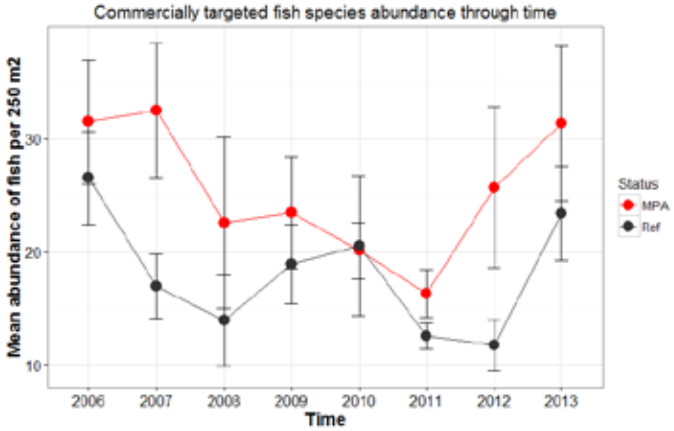
Map of survey sites. Ecological surveys were conducted at 5 coral reef MPAs and 4 seagrass bed MPAs and at their respective reference sites (unprotected sites located nearby) (Gouezo 2017, PICRC Monitoring Report, unpublished).

Indicator	Grade	State
Effectiveness of MPAs on Resource Biomass on Reefs	**Good** *Basis for Grade:* Subjective, based on "significantly more" abundance and biomass.	2014: • Resource fish significantly more abundant and larger in MPAs compared to unprotected areas nearby. • Top predator biomass five times larger inside MPAs than at unprotected sites • Top predators accounted for 1/3rd of fish biomass in MPAs, but only 1/10th in adjacent unprotected areas. (Friedlander et al. 2014/National Geographic Pristine Seas report) 2006-2013: • MPAs significantly increase biomass of commercially-valuable species (excluding Maml and Kemedukl) • It is still unknown if MPAs only can sustain overall fish populations over time as the biomass and abundance of fish outside MPAs remains low even after 10 years or so of protection. • See Figure top left this page; Map p. 36. (Gouezo 2017, PICRC Monitoring Report, unpublished)



Change in commercially-targeted fish species (excluding Maml and Kemedukl) and protected species biomass (±SE) within coral reef MPAs and reference sites through time.

Effectiveness of MPAs on Number of Fish	**Good** *Basis for Grade:* Subjective, based on desired trend.	2006-2013: • MPAs significantly increase fish abundance (including Maml and Kemedukl) • See Figure bottom left, this page. (Gouezo 2017, PICRC Monitoring Report, unpublished). 2007 (Select locations): • Higher fish abundance in Ngelukes (closed since 2003) versus Uedangel (open) • Higher abundance of corals, turtles, and giant clams at Ngeruangel versus Kayangel (more fish at Kayangel). (PICRC data in Hay and Bells 2007)



Change in commercially-valuable fish species (including Maml and Kemedukl) and protected species abundance (±SE) within coral reef MPAs and reference sites through time.

Indicator	State	Grade
Length of time as a protected site	2015: The years that a site has been protected correlated with higher PAME scores for biophysical features and conservation effect. (2015 PAN Status Report) Numerical abundance and biomass of the three grouper species was 54% and 71% higher, respectively, at Ngerumekaol (closed since 1976) compared to Ebiil (closed since 1999). At Ebiil, population size of Tiau (*Plectropomus areolatus)* was lower and more variable than at Ngerumekaol. There were also lower numbers of Hludel temekai (*Epinephelus fuscoguttatus)* compared to Ngerumekaol and a near total absence of *Epinephelus polyphekadion*. (Golbuu and Friedlander 2011)	**Good** *Basis for Grade:* Subjective, based on desirable trend: Longer time as a PA leads to better conditions; plus relatively high differences between Ngerumekaol and Ebiil.
Protected Area (PAN) Condition versus Budget/Staff	2008-2015: • States that received a higher cumulative amount across a four-year period had higher PAME scores in Biophysical and Conservation Effect categories. • Increased staff, associated with higher PAN budgets, correlated with higher PAME scores in the three Biophysical PAME categories. (2015 PAN Status Report)	**Fair** *Basis for Grade:* Subjective, based on desirable trend. Not rated Good because overall the Biophysical and Conservation Effect categories were Poor to Adequate (2015 PAN Status Report).

Pressures and Unmitigated Risks

MPAs have been the focus of significant investment since 1994, which has led to better conditions within them. Pressures on MPAs come from forces such as over- and illegal harvesting, sedimentation, and Climate Change. Few risks to MPAs are entirely unmitigated, as efforts are underway to minimize most risks, albeit to differing levels of effectiveness. The situation is quite different for Terrestrial Protected Areas. Unmitigated risks include poaching and overharvesting, fire, clearing (accidental and purposeful), and legislative weaknesses.

Learning more about Protected Areas

PICRC has taken on the role of serving as the nation's authority on Marine Protected Areas. There is no single authority on Terrestrial or Mangrove Protected Areas. The PAN Office is the authority for all PAN Sites.

Both PCS and TNC also have significant information on Protected Areas.

Monitoring Programs and Gaps

PICRC monitors Marine Protected Areas using its standard monitoring protocol. The Belau National Museum monitors PAN sites and many terrestrial protected areas for birds with protocols developed under the National Program for Monitoring Forest and Coastal Birds. States have individual monitoring plans in their Protected Areas Management Plans. The PAN Office has implemented a Protected Areas Management Effectiveness (PAME) Assessment once, with plans to repeat it every few years.

Beyond birds, however, there is no consistent monitoring of terrestrial sites inside or outside the PAN, a major gap.

Water Quality & Sanitation

Summary and Major Points

Drinking water quality is good

In both urban and rural systems drinking water quality is good and usually meets or exceeds standards. Drinking water is well monitored.

Marine water quality (and by extension streams) is poor

Marine water quality in bays has high sediment levels, and sediment and water are not flushed out well in most bays. Thus, water quality is sufficiently poor enough to cause harm. Sedimentation rates have increased dramatically since the early 2000s (300 to 500%). The causes behind sedimentation (unplanned development, insufficient erosion control, and fire) are largely unmitigated. Sedimentation is closely linked with earthmoving permits, which are increasing, thus the indicator is expected to decline more.

Indicator	State	Trend	Grade
Marine Water Quality (Turbidity), Sediment in Bay	2011: In Diongradid Bay, water turbidity exceeded levels considered harmful to corals. Sediments were constantly resuspended by the winds and currents, and not exported away. (Golbuu et al. 2011)	Increasing	Poor

Notes on trend: Sedimentation and turbidity are linked to earthmoving permits, which are on an increasing trend (See section on Earthmoving, p. 45). In 2006, average water quality parameters for fecal coliform bacteria, turbidity, pH, temperature, DO, and salinity were within set standards (Marino et al. 2008).

Basis for Grade: Subjective. Turbidity is high enough to harm corals. Palau's small estuaries do not effectively shield the reef from riverine sediment. Small estuaries are much less effective in trapping sediment than larger estuaries (Golbuu et al. 2011).

Indicator	State	Trend	Grade
Siltation Rate (Babeldoab)	2011: • Ngerikill: 462.4 tons/km/yr; • Ngerdorch: 9.7 tons/km/yr (Golbuu et al. 2011)	Increasing	Poor

Notes on Trend: Siltation rate increased by 300% (tripled) in the Ngerikiil and 500% (5 times) in the Ngerdorch since 2003 (Calculated from Victor et al. 2004 and Golbuu et al. 2011).

Basis for Grade: Trend likely to get worse, as river sediment yield, reef sedimentation rate, and reef turbidity increased strongly with increasing numbers of earthmoving permits (Golbuu et al. 2011). (See section on Earthmoving, p. 45, which are on an increasing trend). Goals set 4 to 5 years ago are no longer applicable: The GEF5 Project Document goal was based on 2003 data (Victor et al. 2004), calling for a 10% reduction from 150 to 135 tons/km/yr by project end in the Ngerikiil (15 tons/km/yr). This would now have barely any impact.

Drinking water, Turbidity (Airai-Koror Urban system)	2003: After investments, drinking water quality improved greatly with effluent turbidity levels ranging from 1 to 3 NTU. (Kingston 2004)	Stable	Good

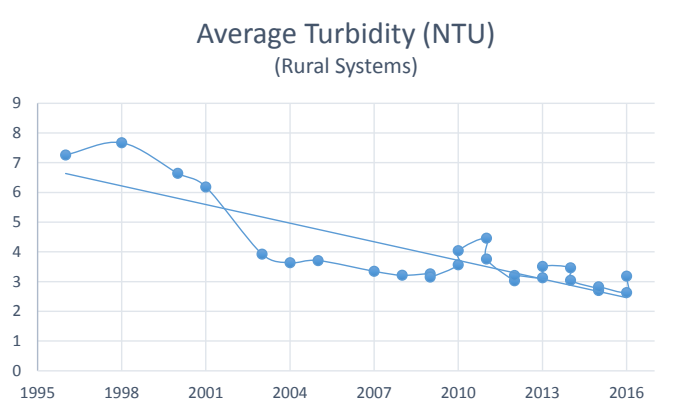
Notes on Trend: Likely to decrease even more with improvements to water and sewer systems in 2017. This will also likely decrease contamination with coliform.

Basis for Grade: Average meets standards for safe drinking water (US EPA 1974; Basis for EQPB regulations).

Drinking water, Turbidity (Rural systems)	• Since 2003, annual average has always been below maximum allowed (at no time over 5 NTU). • For daily readings, NTU above maximum allowed 18% of the time. (EQPB Data 2017, unpublished)	Declining	Good

Notes on Trend: See Figure below. 1996-2001: Annual average was above standard; 2003-2016: Annual average below standard (EQPB Data 2017, unpublished).

Basis for Grade: Average meets standards for safe drinking water (US EPA 1974; Basis for EQPB regulations).



Pressures and Unmitigated Risks

Pressures on marine water quality come from land and are generally unmitigated. Clearing for development and from fire is closely associated with sedimentation. Erosion-control measures appear to be inadequate and there is no spatial planning to reduce impacts from development into marine systems.

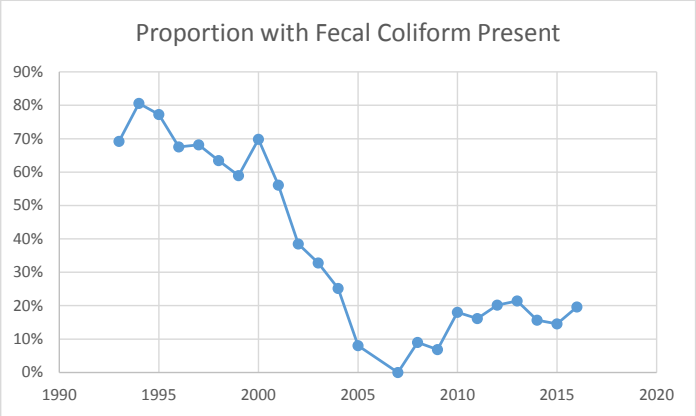
Learning more about Water Quality

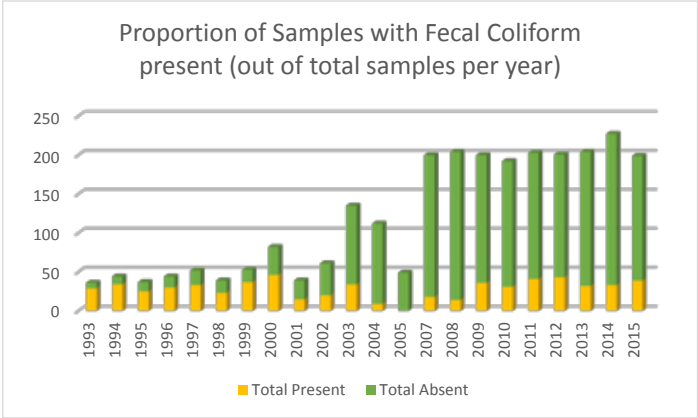
Water quality is monitored by several agencies, including EQPB, PPUC, and the Water Treatment Plants (PPUC /Bureau of Public Works). Management of the systems is by PPUC.

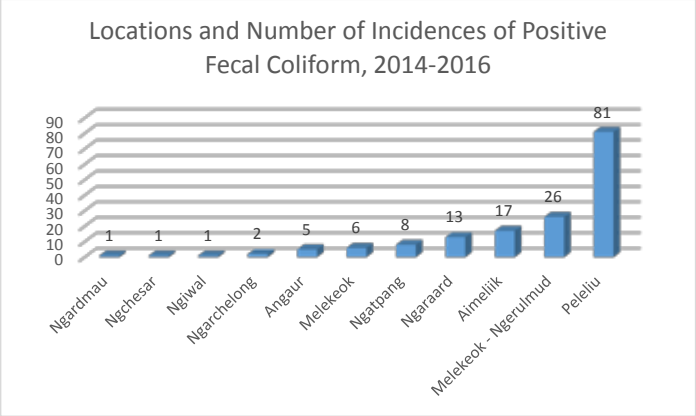
Indicator	State	Trend	Grade
Drinking water, Fecal Coliform (Rural systems)	Between 2014 and 2016, Fecal Coliform present in 15 to 20% of samples (See 3 Figures below). (EQPB Data 2017, unpublished) Monitoring capacity jumped drastically in 2007 (See Figure, right).	Declining	Good

Notes on Trend: See Figures below. Declining proportion of samples with fecal coliform.

Basis for Grade: Average meets standards for safe drinking water. (US EPA 1974; Basis for EQPB regulations).







Access to Sanitation	2010: 84% of population had sewage treatment systems (Kitalong 2012/MDG)	Increasing	Good

Notes on Trend: 2006: 67% had sewage treatment systems; 33% did not.

Basis for Grade: The Millennium Development Goal (MDG) was to "halve the proportion of the population without sustainable access to basic sanitation." Between 2006 and 2010 Palau met this goal (went from 33% without access to 16% without access).

Monitoring Programs and Gaps

Drinking water is well monitored. Marine water quality is monitored less frequently, especially outside Koror, and sedimentation rates are monitored inadequately in rural watersheds. Given increasing sedimentation rates, this is a major gap. There are increasing concerns over saltwater intrusion into the freshwater lens (in outlying islands) (Gerber 2010 / SOPAC), with inadequate monitoring.

Water Supply

Summary and Major Points

Water supply is adequate for now, but more growth will stress the system

Demand is expected to increase beyond capacity by 2020. Current supply cannot meet existing demand during drought. Storage is inadequate.

Improved drought monitoring is needed

Droughts are expected to intensify with Climate Change (Appendix 1). Improved water supply monitoring and management should include clear thresholds for implementing water hours and rationing.

Indicator	State	Grade
Water Supply, Airai-Koror Urban system	Current demand supplied: 1.46 billion gallons/year. The Ngerikiil River in Airai supplies 3 million gallons of water each day to the Koror-Airai Water Treatment Plant, which is supplemented daily by the Ngerimel Dam by 1 million gallons of water. Total of 4 million gallons of water a day distributed, reaching 70% of the population. (Kitalong 2012 /Water Outlook)	Fair

Basis for Grade:

- Assuming an annual increase in demand for water per year of 2% (equivalent to the assumption on population growth), total annual water demand by 2020 will be 1.49 billion gal/yr up from 1.46 billion gal/yr year in 2010 From Kitalong (2012 /Water Outlook).
- System needs to increase storage capacity beyond existing conditions to meet increasing demand.
- Current yields from water sources for the Koror–Airai water supply are insufficient to meet current demand during periods of prolonged drought.
- Daily Ngerikiil flow is 20 millions gallons/day.
- Droughts expected to intensify with Climate Change (Appendix 1).

Access to Public Water Supplies	90% of households have access to piped, treated water. Rural supplies serve 80% of communities outside Airai and Koror. (Kitalong 2012)	Good
Water Tank Ownership	70% of Babeldaob own rainwater tanks, used to buffer drought. (Kitalong 2012)	Fair

Basis for Grade: Subjective.

Earthmoving & Land Cover Change

Summary and Major Points

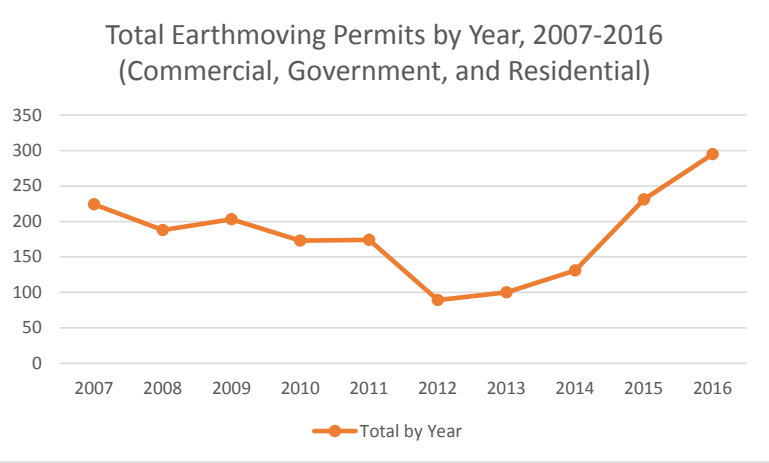
Earthmoving has increased drastically and is associated with sedimentation and habitat degradation

The number of Earthmoving and other permits has increased drastically since 2012, without concurrent increases in ability to manage and monitor: The number of staff who inspect and permit projects for the entire Republic has been at 3 to 5 positions since 2007 and EQPB's budget has been steady at around $400,000/year. Sedimentation into freshwater and marine habitats increases with the number of permits. Commercial, nonprofit, and government permits are increasing and affect significantly more land than residential permits.

There is little capacity to monitor land change

Baseline data are old and of low resolution, and no agency has the capacity to compile land change data from all sources, although PALARIS is poised to do so. There is little to no spatial planning based on land type and suitability.

Indicator	State	Trend
Number of Earthmoving Permits	See Figures, this page and next[9]: • 2016: 295 permits, the highest number issued in a decade • Clear increasing trend since 2012	**Increasing** (Color code considers environmental impact only)



Notes on Trend: See Figures, this page and next.

Earthmoving permits are linked with marine and freshwater quality through sedimentation. River sediment yield, reef sedimentation rate, and reef turbidity increased strongly with increasing numbers of earthmoving permits (Golbuu et al. 2011; see section on Water Quality).

Many of the unmitigated risks listed throughout this report arise from unsustainable land practices (such as clearing and earthmoving) and associated erosion and sedimentation.

[9] Figures graphed using data in EQPB (2017/Annual Summary Report); EQPB Performance Reports 2007-2012; and quarterly Economic indicators sheets 2013-2016 on Palaugov.pw.

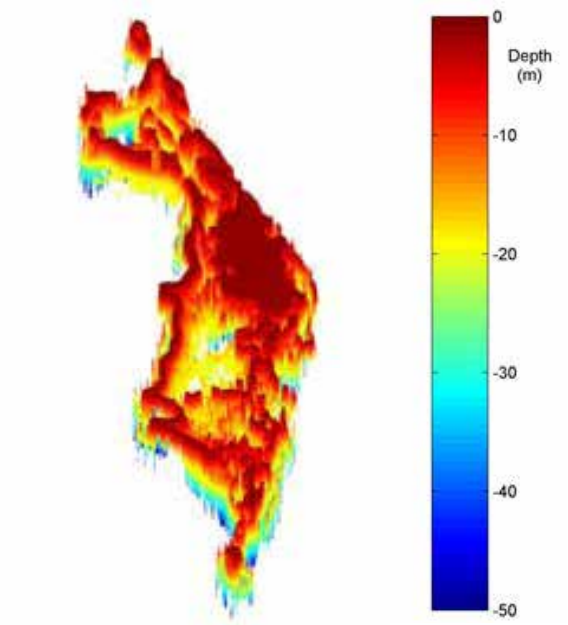
Pressures and Unmitigated Risks

Although Earthmoving is regulated, EQPB does not have sufficient resources to manage and monitor every project so that it maintains adequate erosion control and protects the environment, especially with the increased rate of growth in development since 2012.

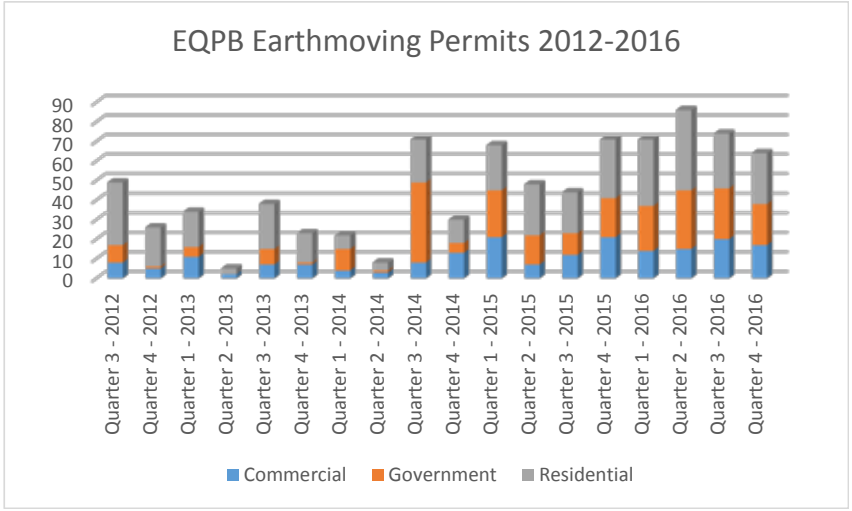
Even before projects get to EQPB, there is little to no spatial planning for appropriate land uses based on land type. Mitigating these risks might mean regulating land uses based on spatial characteristics, little of which occurs now.

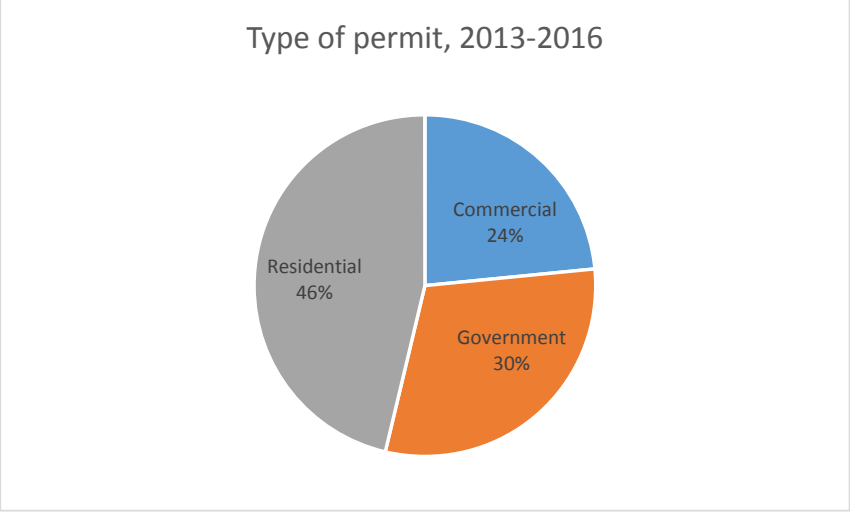
Learning more about Earthmoving and Land Cover Change

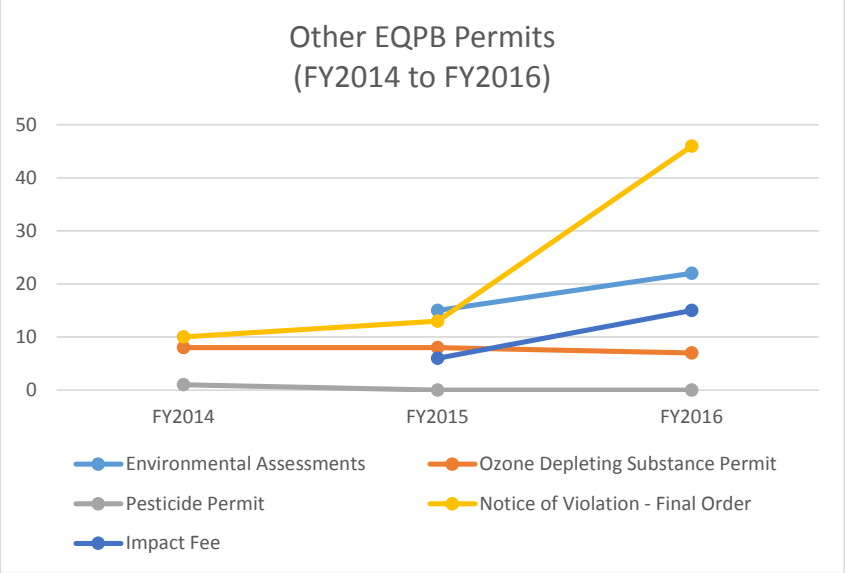
EQPB regulates earthmoving and PALARIS collects data on land cover and is developing new layers to show land cover change; these were not ready in time for this report. There is no clear authority on bathymetry (ocean depth). PICRC has some information, but this is project-based. Bathymetry was modeled in 2003 (Skirving et al. 2005) and in 2012 (KIOST 2013).



Bathymetric map of Palau. Such maps are used to model ocean currents and predict areas of heat stress and possible bleaching (Skirving et al. 2005).

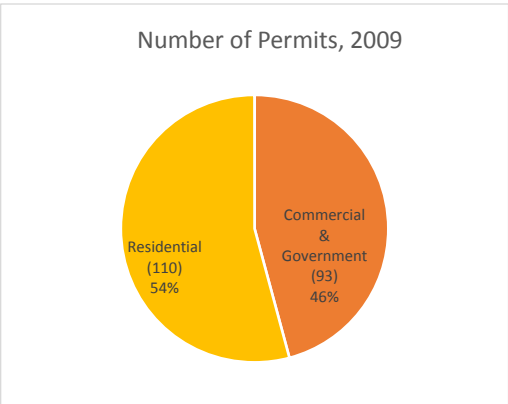


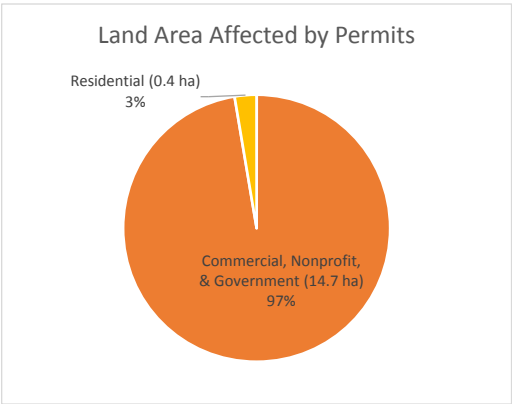




Indicator	State	Trend

Type of Earthmoving Permits / Land Affected by Type	See Figures, below (2009 report included square meters affected):
	• Increasing number of commercial and government permits/projects: Average of 77/yr from 2009-2012; Average of 106/yr from 2013-2016.
	• Area affected by commercial, nonprofit, and government permits is much higher than that affected by residential and minor earthmoving:
	  • 2009: Residential/Minor earthmoving affected 0.4 hectares (4% total area affected)
	  • 2009: Commercial, nonprofit, and government earthmoving affected 14.7 hectares (96%).
	(EQPB Performance Report 2009)
		Increasing
		(Color code considers environmental impact only)
		
		Notes on Trend: See Figures, this page and next. The majority of impact comes from commerical, nonprofit, and government permitted projects, which have increased in number. Increasing number of permits is linked with increasing river sediment yield, reef sedimentation rate, and reef turbidity (Golbuu et al. 2011), which degrade marine and freshwater habitats. There may also be direct loss of habitat (such as forest).
		
		Commercial, nonprofit, and government permits affect significantly more land.





Monitoring Programs and Gaps

Tracking land cover change is a major challenge, as no agency in Palau has the needed capacity (time, budget, baseline, equipment, skill, or mandate) to compile information from all sources of land cover change. PALARIS is building a significant database of information, most of which is spatially-linked (can be mapped). Expanding a multi-agency process to feed spatially-linked information into the PALARIS database will improve spatial monitoring.

A major gap is the lack of fine resolution topographic data (elevation and bathymetry (ocean depth)) for the majority of Palau. Most of Palau is mapped at a 10 meter (30 ft) elevation resolution. This means that Palau cannot adequately monitor, map, and plan for the impacts of sea level rise and storm surges associated with Climate Change (Appendix 1), which are in the 1 to 2 meter range. Filling this data gap with high-resolution (30 cm) spatial data for land and coastal areas requires an investment of several million dollars.

Although it is improving, EQPB needs to consistently track more spatial information about permits, such as square area affected and the type of soil and slope where the development will occur, as well as possibly estimating downstream impacts. Efforts are underway as part of a multiagency GEF-funded project to standardize and modernize collection and sharing of data to better track land cover change and other environmental indicators.

No government agency has a mandate to monitor bathymetry, even though with sea level rise and typhoons Palau's ocean surface has and will continue to change dramatically.

There are currently no island-wide and few state-based spatial Land Use or Master Plans, thus is it difficult to predict land cover change.

Solid Waste & Recycling

Information on Solid Waste was kindly provided by Koror State.

Solid waste management in Koror is good and improving

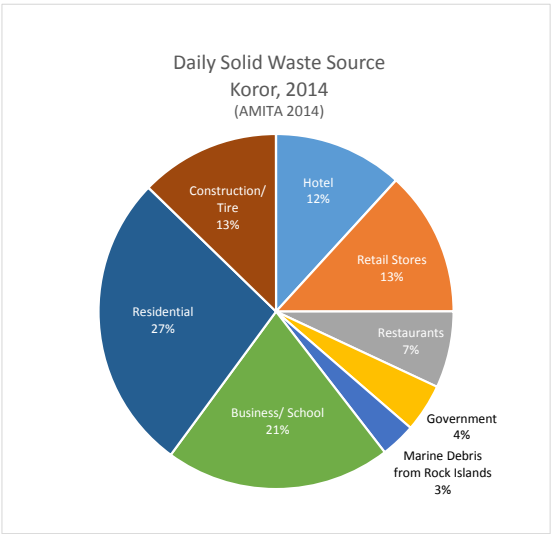
Waste reduction programs, including recycling, composting, and beverage container redemption now divert 51% of Koror's solid waste stream away from the landfill. Compared to other surveyed Pacific Islands (including Guam), Palau is the only island to implement a full suite of Solid Waste Management Practices (prevention, generation, 3Rs, collection, transport, and treatment and disposal). Palau also has many relevant pieces of solid waste legislation in place, although it is missing a comprehensive Solid Waste Act (ADB 2011).

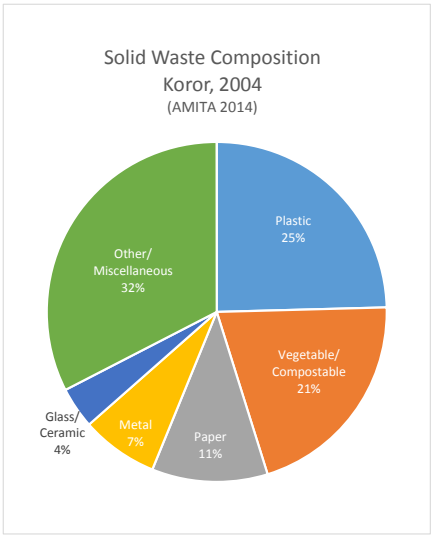
Composting and paper recycling would divert significant waste

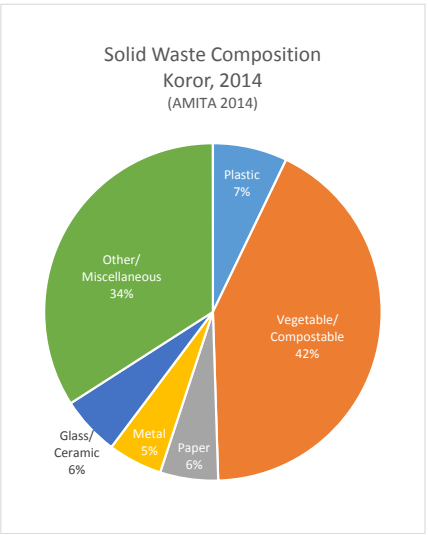
Much of the waste that is produced could be composted. Between 50 and 75% of waste produced by restaurants and hotels is organic and compostable. Paper is the primary waste produced by stores (over 60% of store's total waste) (AMITA 2014).

Total waste generated has increased; waste pollution is a problem

Because of economic growth and increasing tourist arrivals, the total amount of solid waste produced on island (both in weight and per capita) increased by 60%. This has stressed the Koror Landfill, which is operating at capacity. Management of medical waste and hazardous materials are weak (ADB 2014) and improper disposal of motor vehicle batteries is linked with emerging health issues like lead exposure (See the Environmental Health section, p. 55). There is inadequate monitoring of solid waste. Large-scale surveys were implemented in 2004 and 2014 but inadequate regular monitoring, except of recycled and composted items. Koror State monitors recycling.







Indicator	State	Trend	Grade
Metric Tons of Waste Generated / per day, per year, and per capita	2014: Koror: • 16 metric tons/day • = 5840 mt/year[10] • 0.40 kg (0.9 lbs) per capita/day Airai: • 0.22 kg per capita/day (AMITA 2014)	Increasing	Fair

Notes on Trend: Waste generation has increased significantly. Estimated waste in Koror in 2004 was 1365 mt/year (Koror State 2010). The per capita generation rate increased by almost 60%: From 0.25 kg/day in 2004 to 0.4 kg/day. Per capita generation rate is higher in Koror than Airai. Total population fell between 2004 and 2014 from around 19,900 to 17,500; but tourist arrivals grew by almost 60%, from 89,000 to 141,000 tourists per year. Palau's economy also doubled, with GDP (Purchasing Power Parity) going from a low in 2004 of $120 million to $250 million in 2014.

[10] Calculated from daily generation rate x 365.

Basis for Grade: Palau has a lower per capita generation rate than other places: 0.4 kg/day in Koror versus 0.66 kg/day in the Pacific region (Richards/SPREP 2012) and 0.65 kg/day for other tourist destination islands (Hoornweg and Bhada-Tata/World Bank 2012).

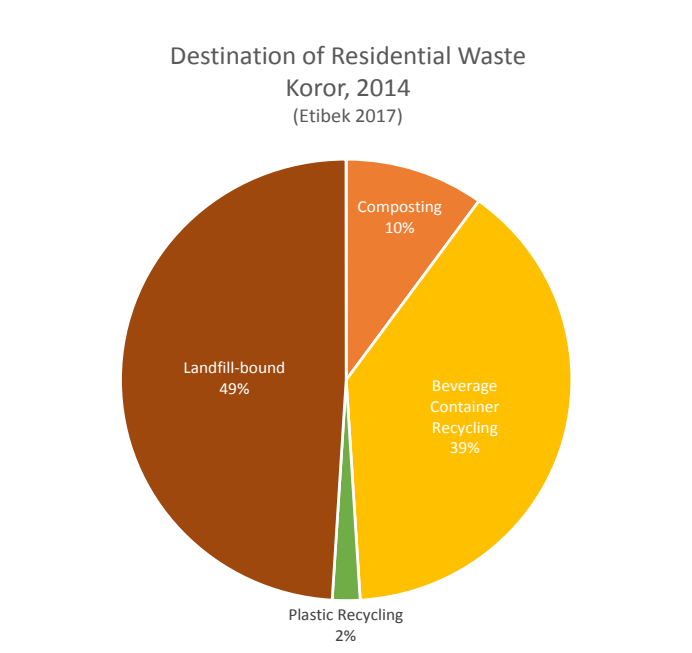
Waste Reduction Rate	2014: For Koror: • Measured: 51% residential solid waste diverted. Palau (whole): • Estimated: 12 to 15% (Etibek 2017)	Increasing Increasing	Good (Koror: Surpassed state goal & 78% towards NBSAP goal) Poor (Nationwide: 18-23% towards NBSAP goal)

Notes on Trend: Trend is inferred from decreases in percent composition of metals, glass, and plastic between 2004 and 2014 (AMITA 2014).

Basis for Grade: The Palau 2015-2025 NBSAP (PCS 2014) established a goal of recycling 65% of Palau's waste. In 2004 Koror State established a goal to reduce solid waste entering the landfill by 8% (Koror State 2015). Even though waste generation has increased by 60%, the removal of 51% of that waste means that Koror State has still met its 2004 goal.

Solid Waste Destination, 2014 (See Figure, right):
For Koror, compared against residential waste amount:

- Organic Waste Composting: Removes 10% of total waste (includes tree trimmings, leaves, grass, leftover food waste, and papers/cardboard)
- Beverage Container Redemption Rate (all, not just residential): 87% of containers redeemed.
- Beverage Container Recycling: Removes 39% of total waste generated.
- Plastic Recycling (non-beverage): Removes 2% of total waste generated. (Etibek 2017)



Dumpsite Compliance	2011: 60% of Dumpsites were in compliance with EQPB regulations (EQPB Performance Report 2012)	Increasing	Fair

Notes on Trend: Compliance has increased significantly since 2007, when only 12.5% of dumpsites were in compliance. 2008: 50%; 2009-2011: 60% compliance (EQPB Performance Reports 2007 to 2012).

Basis for Grade: Palau is 60% towards a goal of 100% dumpsite compliance.

Agriculture & Aquaculture

Summary and Major Points

Agricultural production is increasing slowly
There has been clear growth in the number of species being cultivated for protein, vegetables, and fruit.

Across the board, agriculture and aquaculture production is below demand and below targets
Although agricultural production is increasing and there is strong demand for aquaculture products, supply is far below demand. This is partly due to slow growth in capacity (both technical and financial) and setbacks due to Climate Change (Appendix 1). Loan programs exist to support farm expansion, but there is hesitancy to apply for loans due to perceived difficulties in applying for loans and in putting up collateral.

Several threats to the sector have not been mitigated
Agricultural production faces numerous risks from Climate Change, such as drought and sea level rise (Appendix 1), although some risks have been partially mitigated (such as identification of salt-tolerant species). There are also negative perceptions about agriculture and a perception that there are inadequate markets for agricultural products (despite clear demand). Aquaculture, particularly of giant clams, faces threats from poaching and inconsistent seed supply. Poaching is an unmitigated risk, while supply should improve once the new BMR Hatchery is operational.

Indicator	State	Trend	Grade
Taro production and Climate Change impacts on taro	2015: • 3400 metric tons/yr • 255 hectares (179 upland/76 lowland) • 8% of lowland, 6% of total (16 hectares and 190 tons/yr) lost to salt water intrusion (Del Rosario et al. 2015)	Unknown	Fair

Notes on Trend: An average of 6% of the annual crop (200 mt) is lost per year due to saltwater intrusion (Del Rosario et al. 2015). However, community projects have restored nearly 3.5 hectares of degraded taro patches since 2014, with presumable increases in output (PRI 2015).

Basis for Grade: Far below demand: 41% of desired production based on 2.5 lbs/person/day (50% caloric needs from local carbohydrates) = 8300 mt/yr.

Indicator	State	Trend	Grade
Consumption/ Production of locally produced food	2014: 86% of food expenditures for imported food; 14% on locally produced food (2014 HIES)	Unknown	Poor

Notes on Trend: Expenditures are used as proxy for consumption and production. 1990: Agriculture worth 0.57% of GDP (calculated from 1994 SOE); 2014: 1.6% of GDP (FAO 2014); Output peaked in 2005 followed by steady decline until 2009; then slow increase (Figure 1, FAO 2014, p. 11).

Basis for Grade: Palau is 30% of the way to its goal: Palau Policy to Strengthen Resilience in Agriculture and Aquaculture (Kitalong et al. 2015) goal is for local production of food to meet 50% of needs by 2020.

Agriculture: Non-taro root crop, fruit, and vegetable production/ Production versus capacity	• 2200 mt/yr agricultural production (non-taro root crops, fruits, vegetables) • 51 hectares (non-taro) (FAO 2014) • Crop production reduced by 50% during drought (OERC 2008 / PACC Consultation Report) • 16 Commercial Farms	Increasing	Fair

Notes on Trend: Non-taro, fruit, and vegetable crops in early 2000s = 1770 mt/yr (calculated from FAO 2003 / Central Market Feasibility Study).

Basis for Grade: Imported fruits and vegetables = 1125 mt/yr (34% of consumption); local production = 2200 (66%) of consumption (FAO 2014). However, far below capacity in terms of production per arable land. Maximum arable land = 1000 hectares (2.2% of total; World Bank 2017). Agriculture and Aquaculture Policy (Kitalong et al. 2015) calls for 25% increase in production by 2020.

Household agricultural production **[11] Problems with crop production**	2015 • 25% of households operate some land for agriculture (subsistence or commercial; includes taro); • 593 households reporting having a kitchen garden (13%) • 486 full-time agriculture workers, 616 part-time agriculture workers (2015 Census; 2014 HIES)	Increasing	No Grade Assigned No standards or goals on which to base grade

Notes on Trend: Compare 2015's 486 full-time workers plus 616 part-time workers to 2005's 451 total agricultural workers (2005 Census); this is a large increase in the number of part-time agricultural workers. Full-time agricultural workers also increased by 8%.

[11] Prices and profits were perceived as the main problem for all crops (55%) with pests considered as being the next biggest problem (30%) (Kitalong 2013/MDG Report).

Number of School Gardens/Nurseries	2013: • 2 school gardens/ nurseries (Aimeliik and Melekeok) (Kitalong 2013/MDG Report)	Declining	Poor

Notes on Trend: Nurseries used to be located at many schools, but several have fallen into disuse.

Basis for Grade: Currently at 11% of goal: Agriculture and Aquaculture Policy (Kitalong et al. 2015) target is a school garden at all schools (19 public).

Indicator	State	Grade
Meat and Egg Imports / Production	2014: • 66% of total fresh produce imports are meat and eggs • Offers greatest gains for import substitution with local production • Good demand for local pigs, supply below demand, demand for customs high • 6 farmers buying pig feed from new mill • 7000 eggs imported per day • Estimated capacity (based on live chick imports) in country is 5000 eggs/day from one major producer (PMA). (FAO 2014)	Fair *Basis for Grade:* New feed mill operating far below capacity; able to produce feed for pigs, chicken, and aquaculture. Local egg production offers good area for growth as one producer already producing up to 40% of nationwide consumption (FAO 2014).
Aquaculture Production	2014: • Milkfish and Giant Clams comprise largest production values: • Milkfish: 22 mt / 327,800 pieces / $200,000 per year / 3 companies (2 for food, 1 for bait) • Giant Clams: 16,000 pieces / $85,000 per year / 5-10 small companies (for food and export) • Some coral, mangrove crab, grouper, and rabbitfish aquaculture (Gillet 2016) 2014 and 2015 Giant Clam Exports • 2014 = 17,563 pieces • 2015 = 11,911 pieces (BMR Annual Reports 2014 and 2015)	Fair *Basis for Grade:* Current production is far below demand (especially for exported Giant Clam). 1992 export was around 222,000 pieces (mostly Clam) worth $222,000; thus large decline since 1992 (Division of Marine Resources 1992). There have been reports of inconsistency in seedling supply and poaching for Giant Clams (Gillet 2016). There is strong support for Clam aquaculture at the community level. The Agriculture and Aquaculture Policy (Kitalong et al. 2015) calls for a 25% increase in aquaculture operations by 2020. If managed well, the new BMR hatchery will have capacity to support this kind of growth.

Pressures & Unmitigated Risks

The agriculture sector faces many pressures, from land that is hard to cultivate to negative attitudes about farming. Efforts are in place to help supplement soil, but could be expanded (e.g. provision of mulch). With most agricultural workers being foreign workers, there is little to mitigate the risk of negative perceptions, thereby hindering expansion. Aquaculture has faced risks of seed and feed products that have been tainted (such as with IAS). Efforts to implement biosecurity are expanding but still insufficient to meet all demand. Risks from Giant Clam poaching have not been mitigated.

Learning more about agriculture and aquaculture

The Bureau of Agriculture and Bureau of Marine Resources are the clear authorities on these topics. There are also many technical assistance partners and nongovernmental organizations involved: Palau-Taiwan Farmers Association, Palau Organic Growers Association, and Palau Aquaculture Cooperative Association.

Monitoring Programs and Gaps

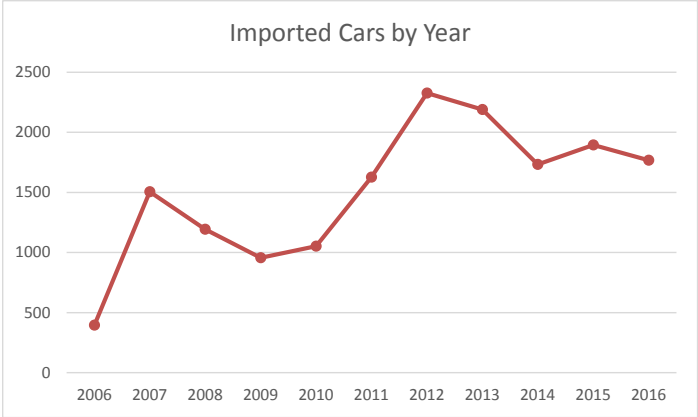
There are few estimates of local production and inadequate monitoring of agricultural production (including inputs, outputs, and losses). Thus it is hard to quantify agricultural production, need, or growth.

Energy Sector & Transportation

Summary and Major Points

Renewable energy and Energy efficiency are increasing slowly; Risks are unmitigated

Renewable solar energy is steadily increasing. Energy efficiency appears to be driven by projects. However, Palau is far away from meetings its 2020 energy goals. Meeting the energy efficiency goal is made more difficult by the rapid increase in imported cars, most of which are older, less efficient models. Without regulations on car imports, these risks are unmitigated.



Indicator	State	Trend	Grade
Renewable Energy Production	2017: 5% of energy produced from renewables (Palau Energy Office 2017)	Increasing	Poor

Notes on Trend: In 2013, 3% of power was from renewable sources, largely grid-connected solar PV systems at the Capitol and airport (Kitalong 2013 / MDG Report). This is an increased from 2011, when 0.3% was from renewables (National Renewable Energy Laboratory (NREL), USDOE 2015).

Basis for Grade: Palau is only 25% of the way to the Palau Energy Policy Goal (20% of all energy produced is from renewable sources by 2020) (Energy Policy Group 2010). Palau's INDC (Intended Nationally Determined Contributions) under the UNFCCC (Climate Change Convention) is even higher: 45% renewable by 2020.

Energy savings/ Energy Efficiency	2013: Reductions of around 1,100 MWh/year (Kitalong 2013/MDG Report)	Increasing	Poor

Notes on Trend: Energy savings from CFL Campaign (820 MWh saved) and PECS Energy Efficiency Project at the Public Works Building (10 MWh) and Capitol (296 MWh) (Kitalong 2013 / MDG Report). Savings calculated using energy costs in NREL, USDOE (2015).

Basis for Grade: Energy savings represent only 4% of the Palau Energy Policy Goal (30% reduction in energy use through efficiency). INDC goal is 35%.

Number of Imported Cars	Since 2006: 17,000 cars imported (Division of Customs 2017, unpublished data)	Increasing No basis to determine benefit or harm	No Grade Assigned No standards or goals on which to base grade

Notes on Trend: See Figure above.

Environmental Health

Summary and Major Points

Ongoing environmental health issues are under control, but emerging issues are challenging

Issues that have been addressed by the Ministry of Health and other agencies for many years are generally in good condition (vector-borne diseases, communicable diseases, and drinking water and sanitation; see Water Quality section, p.41). Emerging issues such as non-communicable diseases and development-driven pollution are poorly controlled.

Capacity to monitor environmental health is insufficient

Insufficient operating funds, competing priorities, and missing equipment hamper identification of environmental health risks, such as changing air quality and product quality in stores.

Indicator	State	Trend	Grade
Proportion of students and adults eating fruit and vegetables every day	Since 2003: • 42% of students eat 1 or more servings of fruit (58% eat fewer than 1) • 44% of students eat 1 or more serving of vegetables • 8% of adults eat recommended 5 servings of fruits and vegetables per day (92% eat fewer than recommended) (MOH 2015/NCD Plan)	Declining	Poor
Healthy School lunches	2015: • Free • 25% of parents "unsatisfied" with healthy options (Lancey, in Morris and Lancey 2015)	Increasing	Fair

Notes on Trend: The trend appears to be getting worse, with students eating fewer fruits and vegetables per day (MOH 2015/NCD Plan).

Basis for Grade: MOH NCD Plan (2015) calls for a 50% increase by 2020 (from 8 to 12% of adults eating 5 servings of fruits and vegetables per day). Non-communicable diseases (NCDs) are on the rise, causing 70% of deaths.

Notes on Trend and Grade: School lunch programs increasingly partner with biodiversity projects to provide fresh offshore fish and vegetables to schools. Lancey (2015) noted that diet in school is becoming more controlled, and students are taking healthy messages about eating home.

Indicator	State	Trend	Grade
Air Quality	2013: • Asthma increasing in Koror. • Increased pollutants in Koror and Airai (Kitalong 2013/MDG Report) 2003: No air quality monitoring equipment, no standards being enforced (Holm and Ridep-Morris 2004/BPOA+10 Review)	Declining	Good
Cases of Dengue Fever	2013: Maximum 10 cases (one month in 2011), otherwise below 10 cases (MOH 2014)	Declining	Good
Exposure to Lead (new emerging issue)	2013: • Increasing number of lead cases • 40% of DEH's Emerging Issues and Special Investigations related to elevated lead levels (Appanaitis 2013/MOH Profile)	Increasing	Poor
Stores inspected annually	2011 and 2012: 37% 2010: 55% of stores inspected (Appanaitis 2013/MOH Profile)	Declining	Fair
Communicable Disease Surveillance	2011: • One of best communicable disease surveillance systems in region • Tuberculosis is a problem • Leprosy increased slightly (WHO 2011)	Stable	Good

Notes on Trend: Assumed decline, based on increase in Asthma cases and increasing number of vehicles in country (See Energy Sector and Transportation section, p.53). Palau's Compact Road EIS found that motor vehicles contributed 97% to carbon monoxide emissions in Palau (US Army Corps 1998).

Basis for Grade: Air Quality still thought to be good. Palau received a score of 100 from Yale University's 2014 Environmental Performance Index (Yale 2017).

Notes on Trend and Grade: 2011-2013: Declining total number of cases. Rates of vector-borne disease declined as the Division of Environmental Health (DEH) conducted weekly mosquito surveillance in Koror. DEH has identified seasonal fluctuations in pupa/larva counts and reacts to keep these counts below threshold (10).

Notes on Trend and Grade: Increasing number of cases, from inadequate management policy/practices for handling and re-purposing used motor vehicle batteries.

Notes on Trend and Grade: Decrease in capacity to inspect due to staff shortages and competing priorities (Appanaitis 2013/MOH Profile).

Notes on Trend and Grade: "Palau regularly reports outbreaks of infectious disease on PacNet. In 2009, MOH detected and controlled outbreak of pandemic influenza A (H1N1). Collaborative initiatives among principal health officials, health specialists and multisector community leaders in place" (WHO 2011).

Pressures & Unmitigated Risks

Economic growth in Koror—and the challenges it creates such as increased pollution and increasing numbers of stores to be inspected—is generally unmitigated.

Monitoring Programs and Gaps

The Division of Environmental Health (DEH) under the Ministry of Health is a clear authority on Environmental Health. EQPB also monitors water quality and has authority over sewage systems.

Alien Invasive Species

Summary and Major Points

Systems are in place to address Invasive Alien Species, but there are gaps

With an active National Invasive Species Committee (NISC) and a new Biosecurity Office, systems are in place to detect and respond to IAS. Transition in the NISC and Office do mean that additional capacity building is needed and there is fragmentation. There are gaps in management and controls target relatively few species (such as vines and rats), leaving many IAS without any response. Palau is at very high risk from both external introductions (such as the Brown Tree Snake) and internal invasions (such as the Macaque).

IAS management priorities need to be aligned

Environment and development/commercial agencies have conflicting views on some IAS, such as Tilapia. Even within Natural Resources agencies, there are conflicts. For instance, landscaping and aquaculture imports have included species discouraged by the biodiversity conservation sector.

Indicator	State	Trend	Grade
Alien Invasive Species (Plants)	2014: • "No new plant pests or diseases" • 4 species subjects of eradication programs • 53 species currently in Palau are invasive or potentially invasive. • 95 species that are invasive or weedy elsewhere and are common, weedy or cultivated in Palau. • 15 native species (or Micronesian introductions) that exhibit aggressive behavior (NISC 2014)	Stable	Fair

Notes on Trend: "This is an indication that our Plant Protection and Quarantine Service (PPQS) is doing a good job" (NISC 2014). 1994: 428 known alien plant taxa out of 1258 plants (34%) (Otobed and Maiava 1994/1994 SOE).

Basis for Grade: Although new introductions are few, invasive plants have expanded noticeably in Babeldaob and Koror and are difficult to control.

Indicator	State	Trend	Grade
Alien Invasive Species (Birds)	2016: • 5 IAS birds: (Eclectus Parrot, Greater Sulfer-crested Cockatoo, Chestnut Mannikin, Red Junglefowl, and Eurasian Tree Sparrow) (PCS 2010)	Increasing	Fair

Notes on Trend: The sparrow is a recent introduction and spreading in Koror from Malakal. In 1994 there were only 4 IAS bird species (1994 SOE).

Basis for Grade: Although the number is small, there have been no control or eradication efforts. Populations of parrots and cockatoos were stable from 1994 to 2005, with the cockatoo "common" in the Rock Islands (VanderWerf 2007). The parrot and cockatoo eat the endemic and threatened *Ponapea palauensis*, an endemic palm tree (Costian et al. 2002 & 2013).

Location of Macaques	2014: Feral monkeys seen in Peleliu, Rock Islands, Koror, Babeldaob, Angaur (NISC 2014)	Increasing	Poor

Notes on Trend and Grade: Macaques have spread from Angaur. Unknown whether observed monkeys have been lone individuals or part of established populations. Macaques are devastating to biodiversity and agriculture, create economic damage, and can transmit diseases to humans.

Established Invasive Alien Species of concern	2013: • Long-tailed macaque monkey (*Macaca fascicularis*), • Tilapia (*Oreochromis mossambicus*), • Mikania (*Mikania micrantha*), • Cogon grass (*Imperata cylindrica*), • Philippine Fruit Fly (*Bactrocera philippinensis*), • Praxelis (*Praxelis clematidea*), • Water Hyacinth (*Eichornia crassipes*), • Singapore ant (*Monomorium destructor*), • Giant reed (*Arundo donax*), • Cycad scale (*Aulacaspis yasumatsui*), • Rats (*Rattus spp.* 3 species) • Cats (US Navy 2013; All above except Cats)	Fair

Basis for Grade: Compared to other locations in Micronesia, Palau has fewer established species. Knowledge of IAS is relatively high and some control efforts are underway already. Supportive legislation is in place, although regulations are needed. There are offices with clear responsibility, but without the full capacity to monitor and manage.

Potential Invasive Alien Species of concern	2013: • Brown Treesnake, • Little Fire Ant, • Coqui Frog (*Eleutherodactylus coqui*), • Red Imported Fire Ant (*Solenopsis invicta*), • Other tilapia species, and hybrids, • Other frogs, • Ivy Gourd (*Coccina grandis*) (US Navy 2013)	Fair

Basis for Grade: Not established, but pose significant risks. Mitigation and prevention procedures and equipment are not in place for each species. Palau just starting to implement the Micronesia Biosecurity Plan (US Navy 2013).

Marine Invasives[11] *[11] See section on Select Marine Sites and Species. Also see indicator on Aiptasia, a non-native sea anemone spreading in Ongeim'l Tketau.*	2016: Port surveys identified 4 potential marine pests (Campbell et al. 2016)	Increasing	Fair

Education & Awareness

Summary and Major Points

Environmental awareness of protected areas is high, but some gaps exist

Large investments in environmental outreach and education in the past two decades has led to high levels of understanding of conservation, with an emphasis on protected areas. Monitoring occurs at many levels and by many organizations (nongovernment, national government, and state), both as part of regular ongoing monitoring and as one-time projects. There is little coordination between monitoring organizations, leading to informant fatigue. There is a gap in monitoring awareness and adoption of best practices.

Indicator	State	Grade
Enrollment in Agriculture, Environmental Science, or STEM Disciplines at PCC	2014: • Average of 44 students per quarter • 9% of enrolled students	**No Grade Assigned** No standards or goals on which to base grade
Primary School Students receiving environmental outreach	2016: • Ridge to Reef curriculum incorporated into 5th grade public school curriculum (PCS 2017, unpublished) • 82% of all students engaged in PICRC programs (PICRC 2017)	**Good**
Awareness of conservation initiatives [12]Averaged from 5 individual reports (Koshiba et al. 2016 a-e) with results of socio-economic surveys from Peleliu, Ngiwal, Kayangel, Ngchesar, and Ngaraard. MC = Micronesia Challenge.	• 92% aware of PAN (2016[12]) • 92% aware of State PAs • 86% aware of Bul • 70% aware of PA restrictions • 69% have seen/read/participated in PA outreach • 43% aware of MC (All above from Koshiba et al. 2016 a-e) • 55% PAN Sites have socio-economic monitoring • 78% PAN sites have Adequate to Good Stakeholder Engagement (2015 PAN Status Report)	**Good** *Basis for Grade:* Improving or stable. 2009: 74% of respondents aware of Helen Reef MPA Project; 90% aware of restrictions (Oldiais 2009). 2010: 89% aware of Ebiil MPA; 96% aware of restrictions (Oldiais et al. 2010). 2015-2025 NBSAP (PCS 2014) calls for 30% increase.

Threats

Summary and Major Points

Threats between 1994 (Appendix 2) and 2017 have changed in many ways, although three important threats—1) unplanned development and sedimentation, 2) inadequate coordination across agencies, and 3) insufficient enforcement—have been constant challenges.

Water quality, sanitation services, chemical pollution, and solid waste management have improved since 1994.

In 1994 there was little concern over overexploitation of marine and terrestrial resources. Overfishing and overharvesting are now major threats.

New threats now include impacts from Climate Change (Appendix 1), impacts from tourism growth, and insufficient capacity to manage and monitor the more varied challenges facing individual sectors.

2016

Top Threats to the Environment

(Identified by Nongovernmental organizations, Community-based organizations, environmental partners, and youth during a GEF SGP Strategy development survey, N = 52)

1. Lack of capacity (particularly in chemicals, land use planning, multicultural engagement, sustainable harvesting, and sustainable development)
2. Unregulated / Unsustainable development / Poor uses of land
3. Overfishing/Overharvesting
4. Climate Change related issues (including lack of knowledge)
5. Degraded land or cultural features
6. Lack of awareness
7. - Lack of interest in conservation/Other cares (*tied*)
   - Food insecurity
   - Increased tourism
   - Invasive species
   - Lack of employment options/alternative livelihood options
8. - Poaching (*tied*)
   - No protocols to share or update data or information
   - Problems with water management
   - Loss of traditional knowledge

2016

Top Environmental Issues

(Identified as part of the 1st National Environment Symposium Survey, N = 45)

1. Overfishing/ Overharvesting
2. Leaking sewer/pollution
3. Negative impacts from tourism
4. - Sedimentation (*tied*)
   - Impacts from Climate Change
5. - Low Enforcement (*tied*)
   - Challenges to water quality and supply
   - Poor development practices
   - Lack of land use planning

2007
Top Threats to Conservation Targets
(TNC ERA 2007)

Stresses

1. - Habitat loss (*tied*)
   - Changing species mix/population-age structure
2. Introduction of non-native species
3. Decline in habitat quality or condition (water quality, sedimentation)
4. Habitat fragmentation
5. Decline in habitat quality or condition (habitat structure)

Sources of Stress

1. Climate change (likely longer term source of stress)
2. Overharvesting—fishing, hunting of native animal species
3. Land clearing (roads, development, infrastructure, agriculture)
4. Invasive Animals
5. Invasive Plants
6. - Tourism activities (*tied*)
   - Quarrying / mining
7. - Water Pollution (sewage, oil spills, urban runoff) (*tied*)
   - Wildfires
8. - Overharvesting - native plants (*tied*)
   - Destructive harvesting practices
9. - Solid waste disposal/littering (*tied*)
   - Ship groundings
10. Dredging
11. Land filling/reclamation
12. Pesticide and fertilizer misuse

Unmitigated Threats

Many of the top threats are minimally or not mitigated. There is little to no Land Use Planning, and barriers such as land tenure and supportive regulatory structures are not in place to support it. Even a full suite of best practices to guide development while protecting biodiversity and minimizing sedimentation has not yet been identified. Tourism growth poses threats that amplify without broad-scale planning.

Some mitigating factors are in place to reduce overfishing, such as regulations on size, gear, and seasons. However, this is inadequate to mitigate the demand for reef fish. Estimates of reef fish harvests are old; there is no current measure of reef fishing. Most overharvesting on land is illegal, in part to unmitigated demand and insufficient enforcement.

Although lack of capacity and awareness continually arises as a threat, partners have done a good job at building capacity and awareness for new and emerging topics as they arise.

Impacts from Climate Change are new threats that are largely unmitigated.

Only some threats (such as IAS and Climate Change) are monitored by designated agencies or organizations. Most threats are not monitored; if they are it is through projects and by various agencies.

Conclusions

This report offers a fascinating tour of Palau's environment, highlighting areas where the environment and environmental management are doing well and where additional effort is needed. Thankfully, Palau's coral reefs—the basis for much of the economy—are largely in good condition. Outer reefs on the East Coast are in poor condition following two Supertyphoons, indicating the need to think innovatively about when and where pressure on the reef should be minimized. Improving conditions there will take time, but also may take cooperative effort across states and agencies.

Reef fisheries are in trouble, with declining fish abundance and biomass in numerous habitats. Although Palau has invested heavily in protected areas and has many rules and regulations in place, solving the fisheries problem also requires using new methods to reduce or divert overall fishing pressure.

Illegal harvesting of protected species is a continual problem; and is having a clear negative impact on iconic resources such as Maml, Kemedukl, Mesekiu, Uel, and Belochel. These creatures, so tied to Palauan culture, face the threat of local extinction.

This report shows that Palau's investment since 1994 in quality of life has created a Human/Urban Environment that is largely in good condition and beneficial to the environment and the Palauan people.

This report identifies gaps in knowledge and programming. However, this report did not assess Palau's Environmental legislation or regulatory frameworks. The Asian Development Bank (ADB) recently conducted an independent assessment of environmental legislation in Palau, which, when ready, will identify areas where improvement are needed. The missing Endangered Species List for Palau is a key gap; another issue is inconsistent policies (such as those concerning tilapia).

What does not come across well in this report—because it silently underpins every action and outcome—is the highly collaborative nature of the environment sector in Palau. Environmental considerations and partnerships are present across all sectors: government, nongovernmental, community, and business sectors. This is one of Palau's most prized indicators.

Indicator	State	Trend	Grade
Collaboration among sectors on environmental issues	A wide and diverse local stakeholder body involved in every aspect of Palau's environment.	Increasing	Fair

Priority Action Items

This report identified environmental indicators that need immediate and sometimes drastic action:

- Reducing pressure on reef fish by focusing on reduced overall harvest.
- Increasing the amount of area protected at the highest levels (no-take), including reef, seagrass, and terrestrial areas.
- Immediately reducing (illegal) hunting pressure on the Belochel (Micronesian Pigeon) including by reducing the demand for the bird that comes from multiple sectors of society (including leadership).
- Reducing pressure on large megafauna like turtles and dugong, by reducing demand—especially foreign and non-Palauan—and by increasing enforcement.
- Having a national conversation about Land Use Planning and developing collaborative plans that take into account land type and suitability, especially given the increasing impacts from earthmoving.

Future State of Environment Analyses

Understanding the full extent of Palau's environment and environment sector needs much more than what can be presented in this Report. Future analyses are encouraged, including:

- Identifying traditional knowledge and practices
- Updating existing baselines and making information more accessible
- Assessing budgets and expenses for efficiency
- Examining past investment successes
- Identifying priority budgetary needs
- Assessing organizational capacity
- Assessing legislative strengths and weaknesses
- Assessing/Listing programs
- Identifying Program gaps and redundancies
- Strategic Planning for individual sectors
- Management Effectiveness assessments
- Cataloguing a bibliography and digital library
- Making predictions
- Identifying and filling research/analysis needs
- Describing environmental histories
- Assessing alternatives and scenarios.

Gaps in monitoring and understanding

This report identified areas where there is inadequate monitoring or knowledge about Palau's environment. Priority indicators or environmental conditions that need to be better understood include:

- Fishing pressure on reef fisheries (including both reef fish and macro-invertebrates), and local reef fish Maximum Sustainable Yield (MSY)
- Local MSY for offshore fisheries
- Bats
- Protected and culturally important megafauna
- Plants—including Endangered Plants and Palau's ability to manage plants
- Impact of mangrove change by location
- Fire
- Better information about Earthmoving and its impacts, including consistent monitoring and reporting of spatial impacts of development projects
- Land cover change over time; and Land cover change versus national and local goals
- Sediment in bays/rivers (outside Airai) over time, especially in response to environmental management and Climate Change
- Water supply (especially in drought)
- Dive sites
- Marine invasives
- Nationally important sites that fall under state jurisdiction (in states without capacity)

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Appendix 1: Predicted Impacts from Climate Change on Food Security

This section taken from Gupta and Padilla (2017, GCF Application, unpublished).

Sea Level Rise

Climate Indicator

1. Satellite data indicate the sea level has risen in Palau by about 0.35 inches (9 mm) per year since 1993. This is larger than the global average of 0.11–0.14 inches (2.8–3.6 mm) per year. (PACCSAP 2015).
2. By 2030, under a very high emissions scenario, this rise in sea level is projected to be in the range of 3.1–7.1 inches (8–18 cm) (PACCSAP 2015). Over the long-term, sea level rise will be around 10 inches by 2050 and anywhere between 16 to 35 inches or more by the end of the century (2090 or four generations) (TNC 2015).

Impacts

1. Reduced coral growth and associated declines in reef fisheries for already stressed reefs.
2. Rate of coral growth generally can keep up with sea level rise, *except* where reefs are facing other stressors, such as fringing reefs (pollution) and overfished reefs.
3. An average of 31% reduction in coral reef productivity (some areas with 60% mortality).
4. Regular, constant saltwater intrusion into taro patches; 6% of taro crops yearly are lost.
5. El Nino/La Nina years: Higher tides and greater agriculture losses (1998 had 75-100% losses in low-lying taro patches); with 2 years to recover.
6. Coastal erosion and sedimentation onto reefs and marine areas compounding impacts on reefs.
7. Gaps in knowledge leading to uncertainty in planning.

Increased air temperatures

Climate Indicator

1. Annual and seasonal maximum and minimum temperatures have increased at Koror since 1951. Maximum annual temperatures have increased at a rate of 0.36ºF (0.2°C) per decade and mean temperatures have increased at 0.18ºF (0.10ºC) per decade. The number of warm days and warm nights has increased since 1952 (PACCSAP 2015).
2. Projections for all emissions scenarios indicate that the annual average air temperature and sea-surface temperature will increase in the future in Palau. By 2030, under a very high emissions scenario, this increase in temperature is projected to be in the range of 1.1–1.8ºF (0.6–1.0°C) (PACCSAP 2015).
3. There will be a rise in the number of hot days and warm nights (PACCSAP 2015).

Impacts

1. Declines in sweet potato and taro (kukau) when hotter.
2. Increases in temperature-related disease.
3. Air Conditioning and refrigeration costs go up; shorter shelf life of agriculture and fisheries products leading to higher post-harvest losses and waste.

Increased Sea Surface Temperature

Climate Indicator

1. Projections for all emissions scenarios indicate that the annual average sea-surface temperature will increase in the future in Palau. By 2030, under a very high emissions scenario, this increase in temperature is projected to be in the range of 1.1–1.8ºF (0.6–1.0°C) (PACCSAP 2015).
2. Projected decreases in dissolved O2 concentration with depth (Lehodey et al. in Bell et al. 2011)

Impacts

1. Declining coral health.
2. Associated declines in reef fish, compounded by overfishing.
3. Long recovery times for reefs.

4. Bleaching of aquaculture species.
5. Tourist revenues / Employment days down.
6. Changes to depth and spatial distribution of tuna.
7. Increased likelihood of thermal stress on tuna larvae; declines in tuna abundance.

Increased strength of typhoons

Climate Indicator

1. An increase in the average maximum wind speed of typhoons by between 2% and 11% and an increase in rainfall intensity of about 20% within 100 km of the typhoon center (PACCSAP 2015).
2. An overall decrease in the number of typhoons by the end of the 21st century, although those that hit will be stronger (PACCSAP 2015).

Impacts

1. Reefs are inaccessible for days to weeks before, during, and after storms, making it difficult to fish.
2. Crop losses and slow recovery; after storms in 2012 and 2013 local farmer production was below average for at least 6 months.
3. Delays in receiving imported foods; loss of fresh foods on ships. (There were 3-week delays before shipments were back to normal after 2012 and 2013 typhoons).
4. Storm surges and flooding, both in the coastal zone and upland farms, with particularly large losses of coastal taro due to saltwater intrusion.
5. Increased wave action and strength, resulting in increased coastal erosion and sedimentation.
6. Broken coral heads and reef destruction with associated coral mortality and reductions in fisheries.
7. Slow recovery (lasting years to decades) of reefs, compounded by overuse.
8. Damages to property and infrastructure (particularly used for food production), such as the Coconut Oil mill in Kayangel and National Nursery in Ngchesar.

Increased rainfall variability and extreme weather

Climate Indicator

1. The 2015 annual total rainfall of 97.06 inches recorded at the Koror Weather Service Office was the driest calendar year in that station's 63-year post-WWII climate record. Including rainfall readings taken by Japanese observers on Palau during the period 1924-1937, the recent dry conditions still set record lows for the entire 80 years of combined observation (PENSOU-2, 2016).
2. Rainfall during the wet season is projected to increase over the course of the 21st century (PACCSAP 2015). Projections show extreme rainfall days are likely to occur more often and be more intense (PACCSAP 2015).
3. Droughts are projected to become less frequent throughout this century (PACCSAP 2015).

Impacts

1. Increased flooding, from both freshwater sources and sea level rise, increasing erosion and sedimentation, thus compounding stresses on the marine environment and reef.
2. Crop losses, particularly from drought; agricultural production was reduced by over 50% during the 1998 El Nino (drought).
3. Loss of taro, which is stressed by low-moisture situations.
4. Prolonged declines in income during drought due to reduced tourism and reduced water restrictions which impede economic growth.

Ocean Acidification

Climate Indicator

1. Data show that since the 18th century the level of ocean acidification has been slowly increasing in Palau's waters (PACCSAP 2015).
2. Acidity level of sea waters in the Palau region will continue to increase over the 21st century (PACCSAP 2015).

Impacts

1. Shift from coral to algae.
2. Reduced overall reef biodiversity.
3. Associated declines in reef fisheries.
4. Declines in income from tourism.
5. Declines in shellfish (including clams).
6. Increased unpredictability of the survival rate and spatial distribution of tuna.
7. Declines in tuna abundance.

Changes in ocean currents

Climate Indicator

1. The eddies and upwellings associated with the South Equatorial Current and South Equatorial Countercurrent are expected to decline, and the vertical stratification of the tropical Pacific Ocean is projected to increase due to the weakened tropical circulation associated with global warming.

Impacts

1. Changes to and unpredictability of tuna spawning grounds and larvae survival rate.
2. Eastern redistribution of tropical tuna stocks (with potential for overexploitation of tuna in non-PNA States); fewer tuna in Palau.
3. Unpredictability of currents with negative effects

(such as trash arriving on shore from North America) and associated declines in tourism.

Existing Baseline Investments in Food Sectors to counter Climate Change

There have been numerous investments in climate change adaptation of Palau's food sector, but always on an ad hoc basis; most investments have focused on research and planning. Outside of the food sector, there is a major project to improve the Airai-Koror municipal water and wastewater systems. Food sector investments have included:

Fisheries

- Establishment of Palau's EEZ as the PNMS and a Shark Sanctuary. Bilateral investments are improving monitoring and enforcement of the PNMS through provision of vessels and construction of a dock and quarantine facility.
- Significant investment has gone into research and planning for coral reef conservation. The Palau PAN provides over $1,600,000 for community-based conservation of marine and terrestrial protected areas.
- There has been some basic research, deployment of test FADs, and some marketing programs building awareness and support for offshore fishery products.
- With bilateral assistance Palau is building a new $6,500,000 Mariculture Demonstration Center that will be able to produce 2 million giant clam seedlings per year. The Center is designed to support private farmers as well as national reef reseeding programs.

Agriculture

- Research and demonstration sites have identified salt-resistant taro varieties and appropriate methods for growing them; methods have also been identified and tested for added value products.
- With bilateral assistance Palau is growing its pig production capacity; investments include a slaughterhouse, grain/feed mixer, and training and stocking of demonstration farms.
- With bilateral assistance Palau is building a new climate-proofed plant nursery to provide fruit trees.

Decision-Making

- A project is currently underway to provide hardware, software, and processes for sharing of data between government agencies.
- Many national level laws and policies have been developed and endorsed, including a National Climate Change Policy.

Appendix 2: Summary Points from the 1994 State of the Environment Report

General:

- Government of Palau has not yet adopted a comprehensive policy on the environment and conservation
- Forthcoming documents: National Environmental Management Strategy (NEMS), Comprehensive Conservation Strategy (CCS)

Scope of Report

- The report focuses discussion on projects which can be placed on priority order or action by the National Environmental Management Strategy (NEMS).

Major Issues

"The environmental condition of all the Palauan islands could be considered good. Palau's marine environment remains one of the world's most pristine ecosystems" p.2.

- Pressure put on natural resources and on infrastructure, mainly around Koror.
- Depletion of some natural stocks.
- Damage to some natural habitats (particularly marine ones).
- Decline in quality and adequacy of water.
- Decline in quality and adequacy of sanitation services.
- Difficulties in controlling and managing solid and chemical wastes.
- An enabling legal framework already exists, but need for greater clarification of the mandates of resource management agencies.

Most important issues:

- Need for coordination between responsible agencies.
- Need to strengthen enforcement capacity.

Terrestrial environment

Soils

- 17.47 square miles of bogs, half-bogs, and swamplands; Mangrove wetlands are 14.60 square miles of that.

Earth and Mineral Resources

- Only gravel, soils, sand, and corals are mined or dredged.
- Dredging operations are fairly numerous.
- No comprehensive study on overall impacts of the current level of dredging.
- "It is imperative that levels of dredging and mining be balanced with recognition and protection of the requirements of marine and terrestrial organisms which are so vital to the sustainable economic development of Palau" p. 10.
- Average rainfall of 150 inches.
- Babeldaob streams discharge average of 500,000,000 gallons of water daily.

Habitat/Vegetation

- 1258 taxa of plants.
- 839 native plants.
- 65 plant species and 10 plant varieties are endemic.
- Cole et al. study (1987) detailed land areas – no funding for ground verification. *The 1994 Report includes a table with forest cover table by island and type.*
- 75% of lands are covered with native forest.
    - 53% of total area of land is upland forest.
    - Swamp and mangrove 11%.
    - Limited plantation 6%.
    - 0.4% atoll forest and 1.1% casuarina forest.
    - Secondary vegetation (1.8% of total land).
    - 2741 acres used for agroforestry (2.5%).
- Nonforest lands comprise 21% of total land area.

- Marsh, grassland/savanna (16%).
- Cropland (1006 acres/1% total).
- Strand/beach.

Animals

- Up to 5000 species of insect.
- Giant toad – *Bofu marinus* – introduced; and endemic Palau frog (only native amphibian in Micronesia)
- 6 native snakes, no Brown Tree Snake
- Introduced American chameleon, Indian monitor lizard
- Bat populations at healthy levels, although concern over increasing export of bat to Guam.

Birds

- 141 birds have been seen, 50 resident, 8 endemic.
- Cockatoo and Parrot – cause some concern.
- Indications are that most resident bird species have healthy populations. Concern over pigeon and megapodes eggs. Micronesian megapodes on US Endangered Species list.

Terrestrial Issues

- In general, direct exploitation of resources is not the major issue.
- Mostly direct and indirect habitat destruction, for resorts, roads, and agriculture.
- Damage to mangrove forests has been minimal – only significant loss of mangroves was 35 acres in Ngatpang due to causeway construction.
- Water sources being affected by pollution, but extent of impact uncertain.
- Of grave concern is the increasing use of pesticides on farms, also improper disposal of solid wastes and poorly designed landfills, and defects in sewer and septic systems.
- Logging operation in Aimeliik included no provision for replanting of trees for timber.

IAS

- 428 known alien plant taxa.
- *Merremia peltata* displaced native tax in some areas.
- Coconut beetle – controlled in late 1980s.
- 2 introduced birds.

Marine

- Estimated at 1,357 inshore fish species. *The 1994 Report includes a table with estimates of fishing habitat by state.*
- EQPB records show that through the permitting process, more than 371,850 square feet of shallow reef flat habitat have been destroyed by dredging or filling.
- Constant anchoring at dive sites.
- Populations of wild clams and trochus have declined noticeably; well documented. Moratorium in effect on trochus in 1994.

Fishing

- 250 metric tons of reef fish, crab, and lobster landed or exported in 1990.
- Noticeable declines in grouper, rabbitfish, parrotfish, and wrasse.
- 830.6 mt of tuna air-freighted to Japan and sold on sashimi market. Remainder to Taiwan for canning.
- No value-added processing occurs in Palau.
- No data on harvesting of invertebrates.
  - Concern over mangrove crab and coconut crab.
  - Less concern over lobster, sea cucumbers, and clams.
- Mariculture Demonstration Center—a highly successful program—between 1986 and 1990, giant clam seed production increased almost 10-fold, from 116,503 to 1,353,296 per year.
  - Working to develop state demonstration farms and sanctuaries.
  - Intensive commercial and subsistence harvest and illegal poaching by foreign vessels has continued to cause declines in wild giant clams.
- In first 9 months of 1990, restaurants bought 38,050.5 pounds of reef fish, tuna, mangrove crab, and lobster.
- 1990: 487 vessels fish in Palau's water. License fees generated $659,000.

Megafauna

- Estimated 200 dugongs.
- Estimated 150 crocodiles, "declined significantly."

Agriculture

- 1990: generated $440,675 in revenues.
- Major problems are burning and heavy use of pesticides.
- Introduction of animal of plant diseases.

Water and Sanitation

- Water supply and sanitation likely to become issues.
- Concerns over level and quality of water sources.
- Pollution from solid wastes, landfills, public sewers and septics.
- Need for water monitoring program combined with study of lagoon flushing regime.

Pollution

- Not a critical issue in Palau, but concern growing.
- High use of disposable items.
- Solid waste and negative impacts to mangroves

Management of the Environment

- There are adequate legal safeguards, but enforcement and compliance are weak.
- EQPB would like more staff and training opportunities.
- State enforcement programs are more limited; they lack funding and trained personnel.
- One problem is the informal consultation method between EQPB and other resource agencies over the permit review process; permits are issued without proper assessment.
    - Recommend formalizing or mandating consultation over EQPB's permitting review process (e.g. mandate receiving comments)
- No requirement for consultation with regard to foreign investment permitting procedures – e.g. foreign investment permit given without assessment of environmental impact. Creates ill feeling.
- Absence of overall land use plan for the country (e.g. detailing suitable levels and locations for development with reference to carrying capacity and current state of environment).

Upcoming Developments

- Permits requested for new airport (within Ngermeduu Bay watershed), resort in Ngesaol, golf courses in Airai and Melekeok, and more road development (1994).

2017 State of the Environment Report Republic of Palau

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