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FINANCIAL TOOLS FOR SMALL-SCALE FISHERS IN MELANESIA

COMPONENT 1: CLIMATE RISK REVIEW – PNG

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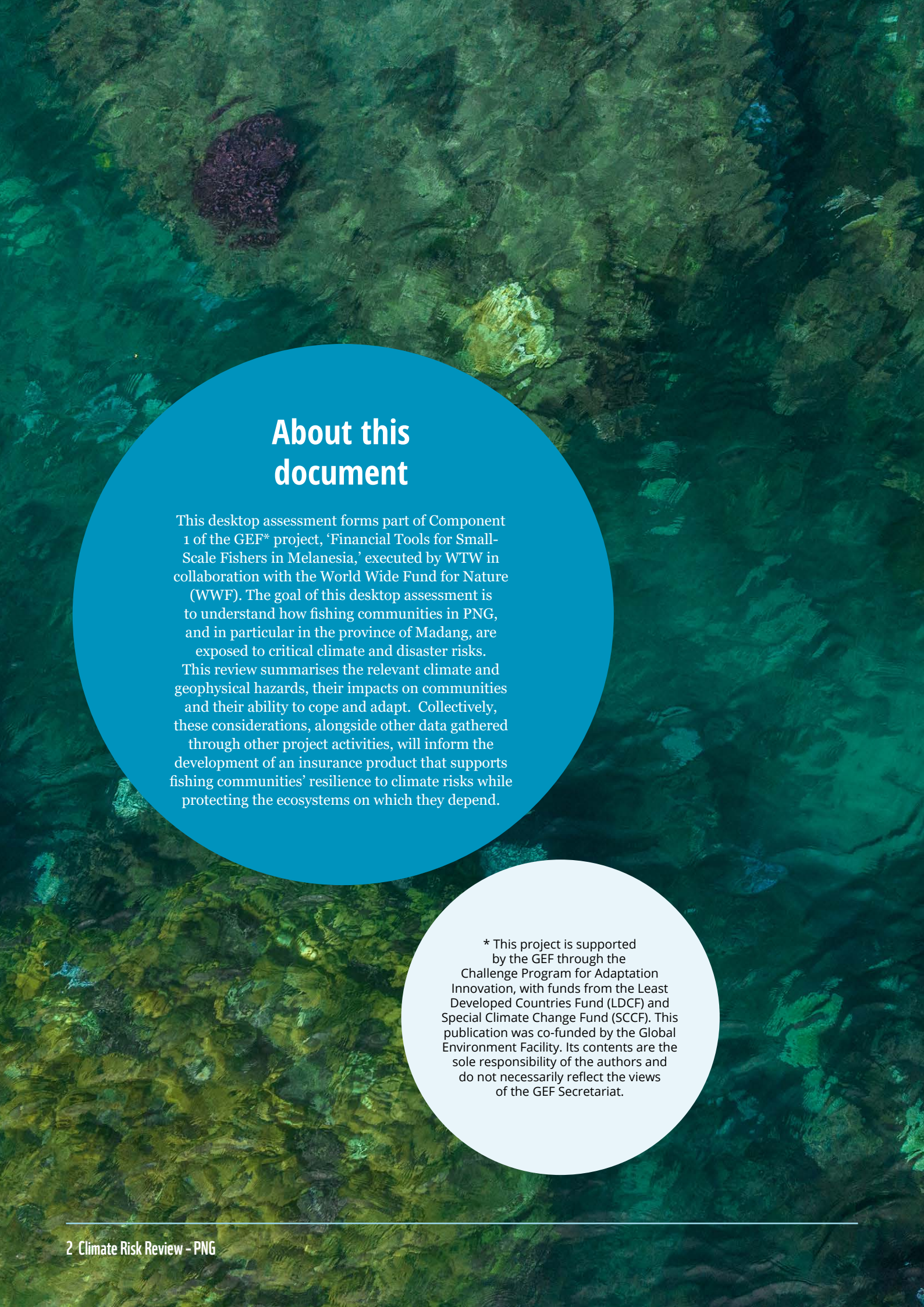

About this document

This desktop assessment forms part of Component 1 of the GEF* project, 'Financial Tools for Small-Scale Fishers in Melanesia,' executed by WTW in collaboration with the World Wide Fund for Nature (WWF). The goal of this desktop assessment is to understand how fishing communities in PNG, and in particular in the province of Madang, are exposed to critical climate and disaster risks. This review summarises the relevant climate and geophysical hazards, their impacts on communities and their ability to cope and adapt. Collectively, these considerations, alongside other data gathered through other project activities, will inform the development of an insurance product that supports fishing communities' resilience to climate risks while protecting the ecosystems on which they depend.

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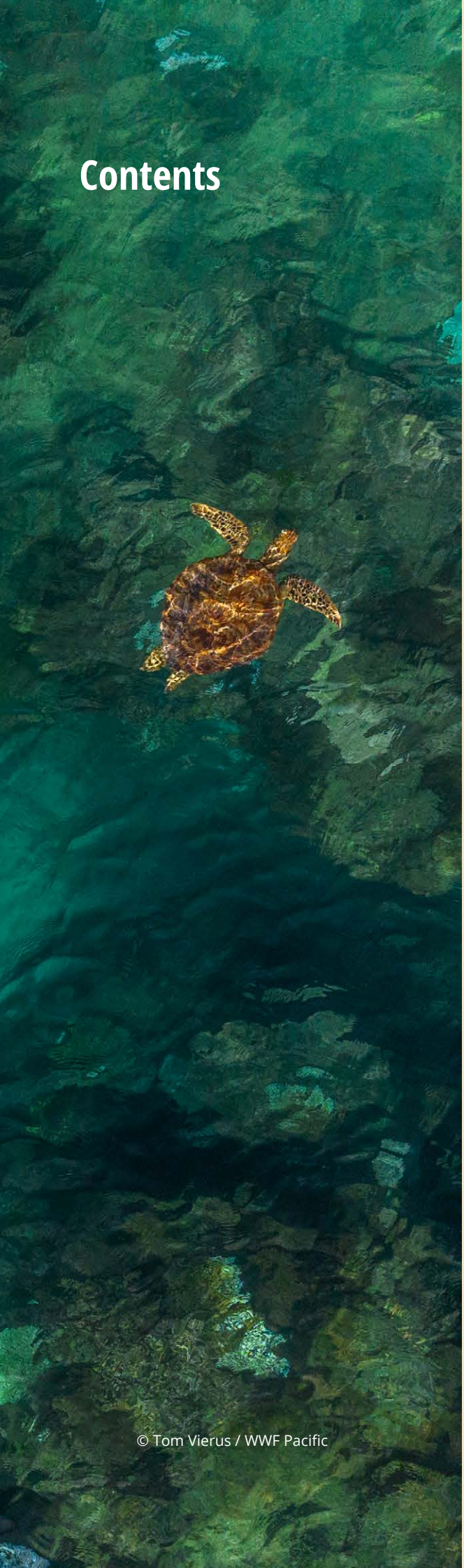

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Definitions and Acronyms

Definitions

The following definitions are drawn from the Intergovernmental Panel on Climate Change (IPCC), where available.

Climate risk: The potential for adverse consequences for human or ecological systems. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. (IPCC)

Climate hazard: A physical process or event (hydro-meteorological or oceanographic variables or phenomena) that can harm human health, livelihoods, or natural resources (World Bank)

Geophysical hazard: A physical process or event that can harm human health, livelihoods, systems, or natural resources (World Bank)

Exposure: The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected. (IPCC)

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (IPCC)

Disaster risk: The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery. (IPCC)

Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects. (IPCC)

Adaptive capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences. (IPCC)

Acronyms

ADB	Asian Development Bank
BCL	Bougainville Copper Limited
CCDA	Climate Change and Development Authority
CBOs	Community Based Organisations
DFCD	Department for Community Development
DRM	Disaster Risk Management
ECMWF	European Centre for Medium-Range Weather Forecasts
EEZ	Exclusive Economic Zone
ENSO	El Niño-Southern Oscillation
ET	Evapotranspiration
EVI	Enhanced Vegetation Index
GMD	Geohazards Management Division
GBV	Gender-Based Violence
GFDRR	Global Facility for Disaster Risk Reduction
IUCN	International Union for Conservation of Nature
IVS	International Visitor Survey
LMMA	Locally Managed Marine Area
LLG	Local Level Government
NASA	National Aeronautics and Space Administration
NDC	National Disaster Centre
NFA	National Fisheries Authority

Executive Summary

Introduction

Climate change is already affecting the Melanesian region disproportionately through rising temperatures, sea-level rise, flooding, coastal erosion, an increase in extreme weather events, coral reef bleaching, and ocean acidification. The Pacific frequently experience tropical cyclones and flooding causing an average annual direct loss of USD 284 million.[1] With a combined population of fewer than 10 million people, annual losses are the highest in the world per a capita basis. As climate change continues, climate-related hazards such as tropical cyclones and extreme rainfall, are predicted to intensify. Over time, chronic climate hazards that manifest slowly, such as sea level rise, and the consequent increase in frequency and severity of high tide and storm surge inundation, will have a more significant impact. For low-lying atolls across Fiji and PNG, and many coastal communities on the main islands, even a small rise in sea level will have huge consequence in terms of loss of land, and other impacts such as saltwater intrusion. Additionally, the effects of marine heatwaves and ocean acidification are contributing to the deterioration of marine ecosystems that serve as crucial habitats for fish and other marine invertebrates. According to the IUCN, ocean warming is expected to have a significant impact on fishery yields and the distribution of fish stocks, particularly for small-scale coastal fisheries.[2] In Fiji and PNG, coastal communities are reliant on fish for livelihood and dependent on fish for protein, with estimates indicating that fish provide up to 90% of animal protein intake in rural areas and 40–80% in urban areas.[3] Thus, climate-related hazards threaten the lives and livelihoods of coastal communities leading to their increased vulnerability.

For this project, Fiji and PNG were selected as they are exceptionally vulnerable to climate risk impacts. This desktop assessment focuses on PNG, in particular the province of Madang, and aims to understand how fishing communities are exposed to and impacted by climate and geophysical hazards. This report begins by providing an overview of climate and geophysical hazards that have historically impacted PNG communities. While there was an emphasis on the hazards experienced by communities in Madang, although it is to be noted that records of historical impacts were incomplete and infrequently directly addressed the Madang province, and that they may not accurately reflect future risk. It then summarises the exposure and vulnerability factors relevant to the target communities, and the existing disaster response and financing mechanisms used, at both a community level and government level.

1 Brown et al., 2014. Evaluating ecosystem-based adaptation for Disaster Risk Reduction Fiji. Available at: https://library.wmo.int/index.php?lvl=notice_display&id=16468#.ZEEEUs7MKUk

2 IUCN, 2016: D. Laffoley and J.M. Baxter, (eds), "Explaining ocean warming: Causes, scale, effects and consequences", Gland, Switzerland: IUCN (2016). 456 pp: http://dx.doi.org/10.2305/IUCN.CH.2016.08.en

3 Farmery et al., 2020. Aquatic Foods and Nutrition in the Pacific. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7761396/

OCHA	Office for the Coordination of Humanitarian Affairs
ODA	Official Development Assistance
OOCD	Office of Climate Change and Development
PDC	Provincial Disaster Centre
PNG	Papua New Guinea
PNGNWS	The Papua New Guinea National Weather Service
PCRIC	Pacific Catastrophe Risk Insurance Company
SIDS	Small Island Developing States
SPI	Standardised Precipitation Index
SMEs	Small and Medium Enterprises
SST	Sea Surface Temperature
TB	Tuberculosis
UNDP	United Nations Development Programme
USD	United States Dollar
WHO	World Health Organisation
WFP	World Food Programme

Figure 1: Map of Papua New Guinea indicating focus site Madang Province located in north central PNG.

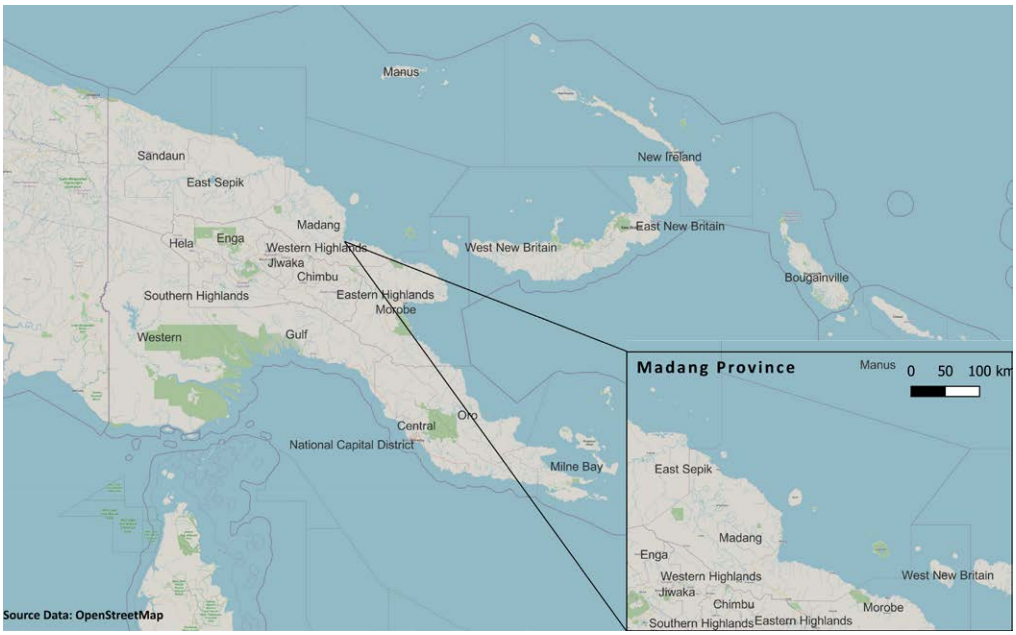


Figure 2: Map of Madang Province, which is composed from six districts: Bogia, Madang, Middle Ramu, Rai Coast, Sumkar and Usino Bundi. The Madang district is the capital of the province. The province shares borders with east Sepki to the west, Enga, western highlands, and Jiwaka to the southwest, Chimbu and eastern highlands to the south and Morobe to the southeast.

What are the main climate hazards impacting PNG?

The table below provides a summary of the main climate and non-climate-related hazards and climate change impacts relevant to PNG.

Hazard	Description	Data Sources
Inland Flooding	**Occurrence:** Flooding occurs during the monsoon seasons: the northwest monsoon prevails from December to April, and the southeast monsoon season from May to October. **Climate Change Impact:** Where there has been an El Niño drought, the impacts of heavy rainfall can be exacerbated due to enhanced surface runoff. **Key Events:** 2004 (torrential rain between Madang and Lae), 2007 (floods linked with TC Guba).	The Papua New Guinea National Weather Service (PNGNWS) NASA Global Precipitation Measurement ECMWF ERA5
Coastal Flooding	**Occurrence:** In the last 15 years, four catastrophic events have occurred per a year, affecting 8,000 people. **Climate Change Impact:** Under the business-as-usual scenario, by 2030, sea level rise is expected to rise by 4-15 cm **Key Events:** 2007 (several days of rain linked to TC Cube, 2008 (tidal waves)	The Papua New Guinea National Weather Service (PNGNWS) NASA Global Precipitation Measurement ECMWF ERA5
Drought	**Occurrence:** PNG's more severe droughts are often correlated with positive ENSO years, and typically occur every 3-7 years **Climate Change Impact:** Unclear. Climate models differ in their projection because of insufficient data and understanding of changes in rainfall variability during dry season. **Key Events:** 1997, 2015-2016	The Papua New Guinea National Weather Service (PNGNWS) NASA Global Precipitation Measurement ECMWF ERA5 NOAA Standardised Precipitation Index (SPI) NASA Normalised Difference Vegetation Index (NDVI) / Enhanced Vegetation Index (EVI) and Evapotranspiration (ET).

Sea Level Rise	**Occurrence:** Since 1993, satellite altimeters have registered a sea level rise of 7 mm per a year. This amplifies the effects of storm surge and has already led to relocation of communities. **Climate Change Impact:** Under the RCP 8.5 high emissions scenario and relative to pre-industrial levels could reach 15 cm by 2030.	Pacific Sea Level Monitoring Project gauges
Rising Sea Temperature	**Occurrence:** Since 1900, average Sea Surface Temperature (SST) in the Pacific has increased by approximately 0.7°C. **Climate Change Impact:** Based on the RCP 8.5 scenario the Pacific pH is projected to decrease by a further 0.15 units into the 2040-2060 period.	Pacific Sea Level Monitoring Project gauges NOAA Coral Reef Watch NOAA OISST NASA GISTEMP
Ocean Acidification	**Occurrence:** With oceans absorbing approximately one third of the carbon dioxide (CO_2) released, the ocean's pH has already decreased from pH 8.2 to 8.1. **Climate Change Impact:** Based on the RCP 8.5 scenario the Pacific pH is projected to decrease by a further 0.15 units into the 2040-2060 period.	Pacific Sea Level Monitoring Project gauges NOAA Coral Reef Watch NOAA OISST NASA GISTEMP
Temperature Changes	**Occurrence:** Papua New Guinea already experiences high maximum air temperatures, with an average monthly maximum of around 31°C and an average November maximum of 32°C. **Climate Change Impact:** by 2090 PNG will see a considerable increase in the likelihood of heatwaves under all emissions and climate change scenarios.	The Papua New Guinea National Weather Service (PNGNWS)

Understanding the key assets and livelihoods exposed and how communities are impacted

Formal analysis of the exposure and vulnerability of Pacific Islands is currently lacking. Studies estimate, however, that 30% of PNG's total population lives within 10km of the coast, which is key to understanding their significant exposure to climate hazards and ocean-related threats. In 2011, PCRIC estimated the total replacement cost of buildings, infrastructure and crops to be 49.2 billion USD. In addition to physical capital, natural capital assets are also important; natural capital provides critical ecosystem services that often reduce the impact of climate hazards and are of particular importance for fisheries-based livelihoods.

Key natural assets for PNG include over 14,535km² of coral reefs and 5,734km² of mangroves, providing valuable coastal protection services. Additionally, coastal fishing represents 85.5% of people's main or second source of income as well as providing communities with their main source of protein. The National Fisheries Authority (NFA) are responsible for the management and development of the fishing sector. The fishing sector is subject to strong international fishing pressure, and climate change will only amplify this, making sustainable ecosystem management of fisheries increasingly important. It is also noted that ecosystems in PNG have not been systematically defined and mapped, leading to difficulties in managing and monitoring ecosystems.

The rural population, whose subsistence fishing and agriculture livelihoods are particularly at risk, is particularly vulnerable; however, alternative livelihood options are limited. Race, socioeconomic status and gender are significant vulnerability modifiers in PNG. There is growing food insecurity in PNG, with key crops upon which communities rely being projected to decline and challenges with declining fish stocks. Gender inequalities also make women particularly vulnerable to the impacts of climate hazards, with gender-based violence incredibly prevalent in PNG, and which disasters only exacerbate.

What existing disaster response and financing mechanisms are there?

The PNG Disaster Management Framework outlines the roles and responsibilities of government agencies involved in disaster management and a National Disaster Risk Reduction Policy for 2018-2030 has also been adopted to mainstream risk reduction at every level. Despite these plans, there is a lack of dedicated funding or mechanisms to easily access funding in emergencies, and lack of clear coordination mechanisms under the current legal framework. The government provides some form of relief measures following a disaster, but with limited public records to target those who need help the most, this does not translate into tangible benefits at the household level. For example, during COVID-19, relief was provided through district grant mechanism, but this was poorly targeted.

In the future, PNG may take out an insurance policy from the Pacific Catastrophe Risk Insurance Company (PCRIC), which would provide funds upon the occurrence of a triggering event; however, the current priority is earthquake.[4]

National bank account ownership rates are very low with only 15% of the population owning a bank account, and this is often even lower in rural areas. Insurance penetration is also low at under 2%, meaning that rural communities do not have much of a financial safety net. PNG has made micro-insurance a priority to address this; however, progress is challenging as local populations have not been exposed to institutions providing private, commercial cover, and there is a lack of basic understanding of what insurance is and how it works.

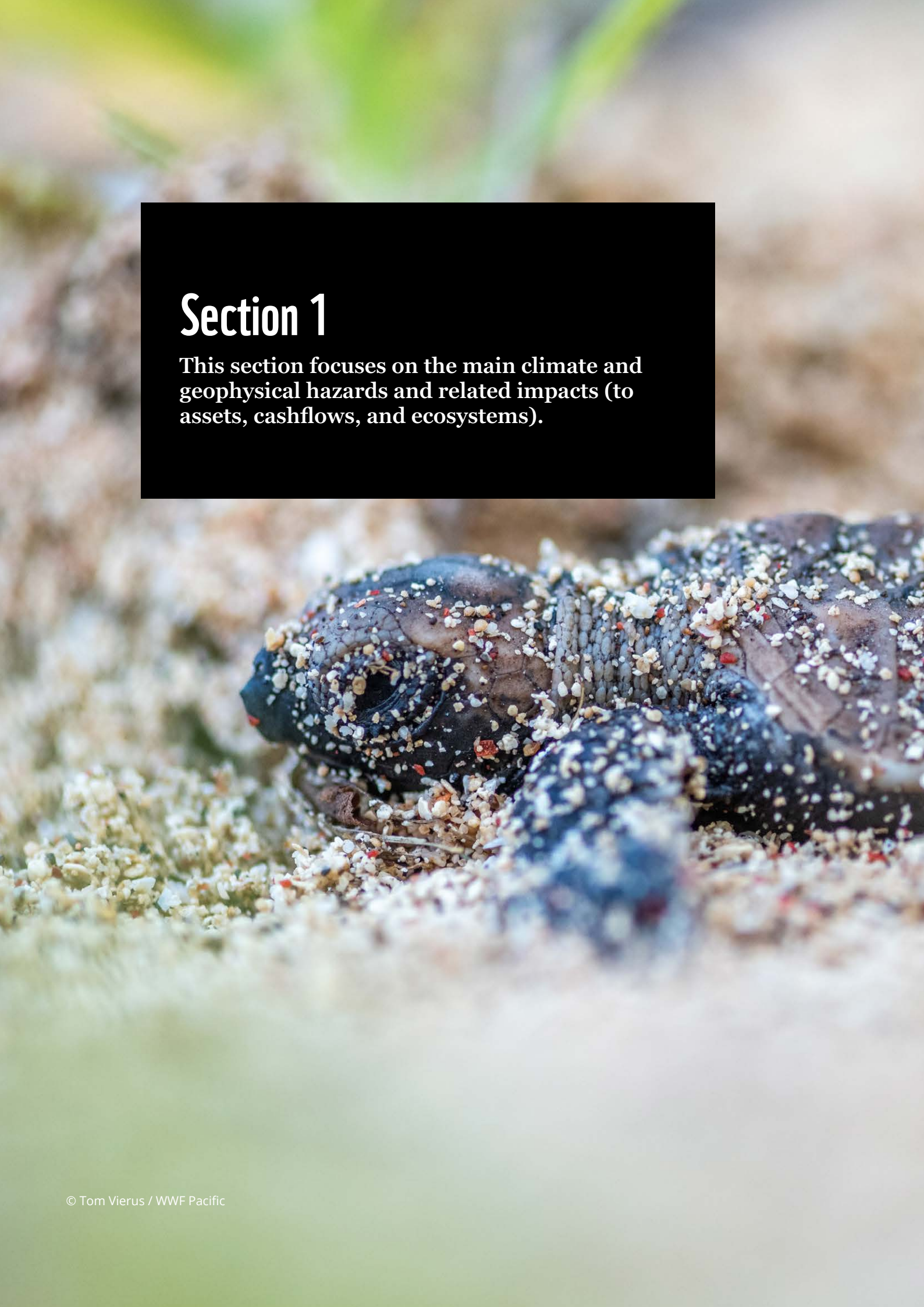
Conclusion

It is clear that PNG faces growing levels of climate risk, exacerbating the development challenges already faced by the country. For fishing communities in particular, the impact on their livelihoods and the natural assets upon which they depend, will be severe. Disaster risk management and response are poorly coordinated and there is a clear lack of appropriate and readily-available government-level financing to support these communities, and a lack of financial resilience within communities themselves. Building this financial resilience is critical, and this project aims to respond to that need.

[4] PCRIC, https://pcric.org/pcric-reaches-out-to-png-following-earthquake/#:~:text=Although%20PNG%20does%20not%20currently%20hold%20an%20insurance,improved%20Disaster%20Risk%20Management%20and%20Disaster%20Risk%20Finance. Accessed 24 April 2023.

Section 1

This section focuses on the main climate and geophysical hazards and related impacts (to assets, cashflows, and ecosystems).



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Climate Hazards

Introduction

Papua New Guinea (PNG) is among the largest Pacific Island states located in Oceania, covering an area of 462,840 km2. The country covers the eastern half of the island of New Guinea, four additional islands, and encompasses over 600 small islets and atolls. PNG is prone to disasters and climate change, and this is reflected in the 2022 INFORM Risk Index, ranking 24th out of 191 countries for risk and having the 16th lowest coping capacity in the world.[5] The highlands, with 2.2 million people in thousands of small villages, are subject to weather extremes of heavy rainfall and drought. The coastal areas and many of the coral atolls are low-lying, and nearly 500,000 people in 2,000 coastal villages are vulnerable to weather extremes and inundation. PNG is one of the largest recipients of Official Development Assistance (ODA) amongst the Small Island Developing States (SIDS); in 2020, it received over 1 billion USD.

The area selected for community engagement is Madang Province (Figure 2). Madang is the capital of Madang Province and is on the north coast of PNG. It belongs to Momase Region and comprises a total of six districts: Bogia, Madang, Middle Ramu, Rai Coast, Sumkar and Usino Bundi. According to the 2011 national census, Madang Province has a total of 493,906 inhabitants (236,325 females, 257.581 males). Madang has PNG's highest mountain ranges, several large islands along its coast, including the volcanically active Karkar, Long Island, and Manam, and one of the most diverse marine areas on the planet, with over 1,300 different species of reef fish. In Madang, pressure on natural resources and climate change has led to over-fishing and the destruction of marine environments in the lagoon areas. This will have a profound impact on communities in PNG, particularly for those who are reliant on fishing for their livelihoods.

Based on observation conducted in Port Moresby since 1950, a steady warming, averaging ~0.1 °C/decade has been observed, and this is expected to continue, with a projected warming of 0.4-1°C by 2030.[6] Climate change and climate hazards will adversely impact communities in PNG, and this review aims to identify the main climate risks and community exposure to gather a comprehensive understanding that will inform product development as part of this project.

[5] INFORM GRI, 2022. Index for Risk Management. European Commission 2022. Available at: https://drmkc.jrc.ec.europa.eu/inform-index.

[6] Climate Risk, Vulnerability and Risk Assessment in the Madang Province in Papua New Guinea. Available at: https://info.undp.org/docs/pdc/Documents/PNG/Report_Climate%20Risk%20Vulnerability%20Assessment_Madang.pdf

Flooding

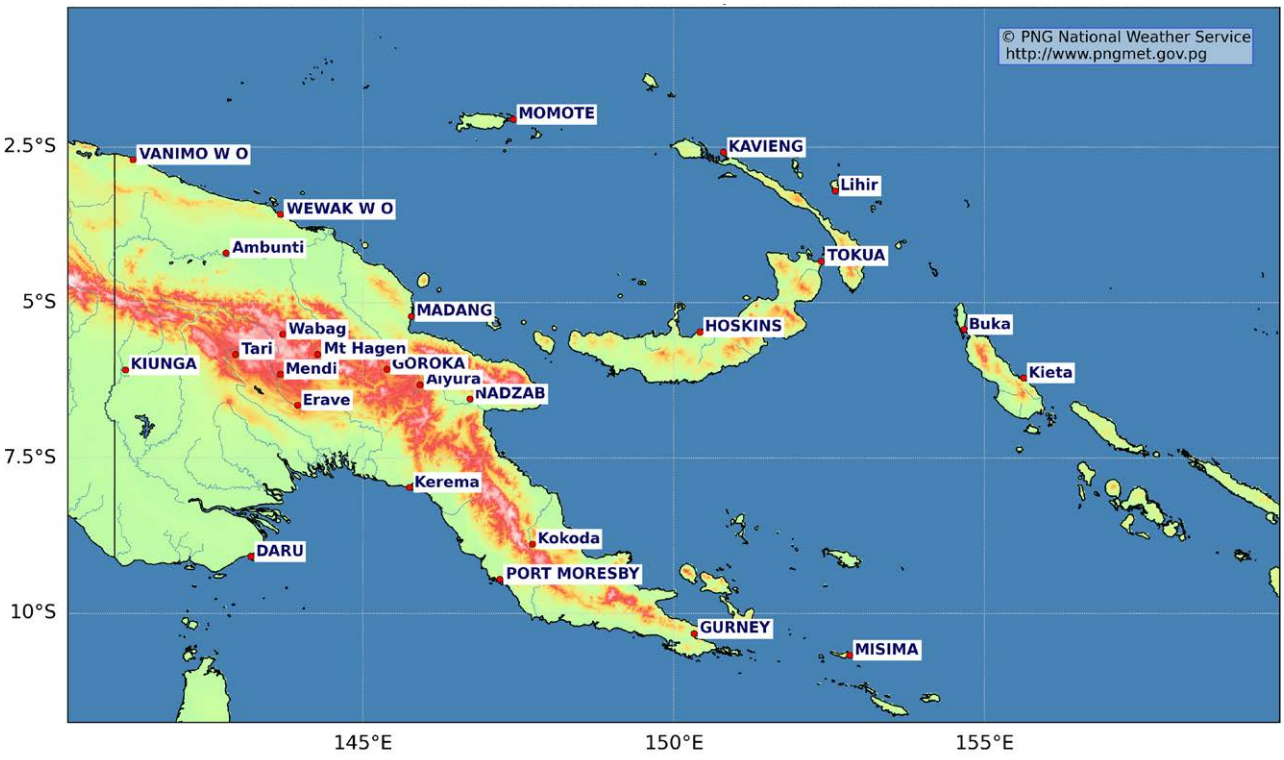
Flooding represents a significant risk in PNG. The United Nations Development Programme (UNDP) suggests that 18% of PNG's landmass is regularly inundated. PNG has one of the wettest climates in the world, with many areas of PNG exceeding 2,500 mm of precipitation per year. This is projected to increase over the course of the 21st century due to climate change. Changes in the intensity and frequency of rainfall events may lead to changes in runoff patterns. However, there is uncertainty in the rainfall projections and not all models show the same results. The Papua New Guinea National Weather Service (PNGNWS) is mandated to collect and archive data on PNG weather. PNGNWS operated under many constraints including a reliance on just 14 meteorological observation station across a highly diverse country with little or no significant presence in most of the provinces (figure 3).[7] Overall, PNG lacks hydro-meteorological data, topo-bathymetric data, gauged data, soil type and land use data, all of which is critical to understanding flood risk.

Inland Flooding

Inland flooding is driven by heavy rainfall impacting valleys and wetlands in both lowlands and highlands. The effects are amplified by steep inclines and deforestation. Based on 19 years of data from PNG, 22,000-26,000 people are affected annually by inland floods, displacing 6,000-8,000 and typically resulting in a few fatalities as well. The annual damage to GDP caused by inland flooding is estimated at USD 73 million (~0.31% of PNG GDP).[8]

Willner et al. estimate that the population affected by an extreme flood could increase by 35,000-56,000 people annually by 2035-2044 as a result of climate change.[9] This is predicted to increase due to population growth, development and climate change. Yet the true impact is hard to assess due to lack of reporting of small flood events.

Figure 3: PNG National Weather Service virtual rainfall stations.



[7] PNG National Weather Service. Available online at: http://www.pngmet.gov.pg/public_wx/index_public_wx.html
[8] UNISDR (2014). PreventionWeb: Basic country statistics and indicators. Available online at: https://www.preventionweb.net/countrie
[9] Willner, S.N., Levermann, A., Zhao, F. and Frieler, K., 2018. Adaptation required to preserve future high-end river flood risk at present levels. Science advances, 4(1), p.1914 Available at: https://www.science.org/doi/10.1126/sciadv.aao1914

Table 1: Overview of major inland flood events in PNG.[10]

Date	Areas Impacted	Description
1992	East and West Sepik	Heavy rain caused flooding of Sepik river
1993	Chimbu province	Heavy rain due to storm hit villages in the western highlands
1993	Bougainville	Heavy rain
1998	Ambunti, East Sepik	Heavy rain followed El Nino related drought
1999	West PNG, Ibongu	Heavy rain caused flooding of Fly and Strickland rivers
2003	Ambunti, Angoram, Pagwi	Heavy rain forced the Sepik river to break its banks
2004	Western Highlands	Two weeks heavy rain caused several rivers to overflow
2004	Mandang province	Torrential rain between Madang and Lae
2005	Morobe province	Heavy rain
2005	Bougainville	Heavy rain
2006	Ambunti - Drekikier	Heavy rain followed El Nino related drought
2006	Western Highlands	Heavy rain
2006	Southern Highlands province	Rush of water down from Mt Giluwe
2006	Highlands region	Torrential rains in the central provinces
2007	Huon Peninsula	2 weeks of heavy rain caused 3 major rivers to break their banks
2007	Oro province, Milne Bay	Tropical cyclone Guba associated with several days of rain

PNG experiences flooding during the two monsoon seasons: the northwest monsoon (December to March) and the southwest monsoon (May to October). Where there has been an El Niño drought, the impacts of heavy rainfall can be exacerbated due to enhanced surface runoff.

The Madang province, similar to the rest of the PNG, experiences flooding during the monsoon seasons. An analysis by AnteaGroup found that floods are expected along the northwest areas of Madang province, in the region around the boundary with East Sepik Province. In the Madang District, the capital of the province, flooding is expected to occur along the downstream part of the Gongoi river which are areas of high population density.[11] The most significant flooding event in Madang occurred in 1998, which left 6,000 families homeless and caused 28 fatalities in the Middle Ramu region.

On the ground recent daily rainfall data is publicly available from Papua New Guinea Meteorological services.[12]

Satellite 30-minute rainfall data is available from NASA's Global Precipitation Measurement on a 10x10km grid. This includes cyclone-associated rainfall, with NASA having produced estimations of total rainfall accumulation from past tropical cyclones. Hourly rainfall data is also available from the ECMWF's ERA5, on a 25x25km grid.

[10] Adaptation Fund Project. Enhancing adaptive capacity of communities to climate change-related floods in the North Coast and Island Regions of Papua New Guinea. Available at: https://www.adaptation-fund.org/projects-document-view/?URL=https://pubdocs/en/935081532123234767/pdf/45-RESUBMISSION-4452-AF-PNG-Full-Proposal-Revised-08Feb2012-clean-copy.pdf

[11] UNDP, 2017. Climate Risk, Vulnerability and Needs Assessment for Morobe, Madang, East Sepik, Northern and New Ireland Provinces of Papua New Guinea. Available at: https://docslib.org/doc/2828687/climate-risk-vulnerability-and-risk-assessment-in-the-madang-province-in-papua-new-guinea-colophon

[12] Available at: http://www.pngmet.gov.pg/

Coastal flooding

Coastal flooding is one of the most important climate-related hazards in the region given most of PNG's settlements are located along the North Coast and the Islands. The impacts not only threaten people in the coastal communities, but also important economic centres, as most provincial capitals and economic centres are situated along the coast, particularly the provincial capitals. Analysis suggests that the average cost of coastal flooding could increase from USD 20 million a year to USD 90-100 million by 2030.[4] On average over the last 15 years, four severe flood events have occurred per year, affecting some 8,000 people. At the coast, ecosystems such as mangroves, estuaries, and coral reefs experience damage due to heavy silt deposits and debris brought in by the flood events. To further exacerbate the situation, climate change under a business-as-usual scenario is expected to cause sea level rise by 4-15 cm by 2030.[13] Such a rise in sea level would increase the impact of storm surges and the risk of coastal flooding.

Table 2: Overview of major coastal flooding events[6]

Date	Areas Impacted	Description
1998	West Sepik	Tsunami following a magnitude 7 earthquake
2002	Aitape, West Sepik	Small tsunami generated by an earthquake
2007	Oro province, Milne Bay	Tropical cyclone Cube associated with several days of rain
2008	East Sepik	Tidal waves hit the northern coast
2008	Manus	Tidal waves hit the norther coast
2008	New Ireland	Tidal waves hit the northern coast

[13] Climate Change in the Pacific: Scientific Assessment and New Research | Volume 2: CountryReports; Chapter 11: Papua New Guinea

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Drought

PNG experiences two types of drought: (1) meteorological (usually associated with a precipitation deficit), and (2) hydrological (usually associated with a deficit in surface and subsurface water flow, potentially originating in the region's wider river basins). While PNG recognises a wet season from November to April, and drier months from July to September, precipitation takes place all-year round, typically in the range of 200–400 mm/month. Areas with a more pronounced wet and dry season include Markham Valley, Bulolo Valley, the Maprik-Angoram area, Eastern highlands, and coastal areas near Cape Vogel, Port Moresby, and Daru. The CCKP model ensemble used by the World Bank (2021), which builds on the RCP2.6, RCP4.5, RCP6.0, and RCP8.5 scenarios, presents an uncertain future for drought in PNG, with a wide variety of model estimates. The model ensemble median estimate would indicate no change in annual probability under all emissions pathways but a small subset of climate models suggests significant increases in the probability of drought. Similarly, Lafale et al.[14] suggest only medium confidence that droughts will decline in frequency. At present PNG faces an annual median probability of severe meteorological drought of around 4%, as defined by a Standardized Precipitation Evaporation Index (SPEI) of less than −2.[15]

Papua New Guinea has experienced severe droughts, often correlating with positive El Niño Southern Oscillation (ENSO). This occurs when an increase in sea surface temperatures and rainfall in the Eastern Pacific Ocean generates greater drought conditions in the region's west, typically every 3-7 years. An analysis carried out by the World Food Programme (WFP) investigated the relationship between the ENSO signal and rainfall in Papua New Guinea. Notably, ENSO mainly was found to affect areas around Gulf and Western while a large area of PNG was found to not be affected by ENSO. In the Madang Province, the influence of ENSO and subsequent changes in rainfall are predominantly located in the highlands.[16]

A recent drought PNG experienced was in 2015-2016 and was one of its worst droughts in history, affecting roughly 40% of the population with almost half a million experiencing food shortages due to crop failures. In 1997 PNG experienced a drought at the time considered to be the 'drought of the century'. The drought combined with frosts (restricted to areas above 1450 m) impacted the plant production and caused large scale famine across PNG. The PNG highland subsistence agriculture communities who inhabit altitudes above 1400 m to 2850 m above sea level and are heavily reliant on frost intolerant sweet potato were amongst the hardest hit.[17] PNG is highly reliant on a fragile environment, and with over 80% of the population reliant on subsistence agriculture, droughts have the potential to cause catastrophic damage.

On the ground recent daily rainfall data is publicly available from Papua New Guinea Meteorological services.[18]

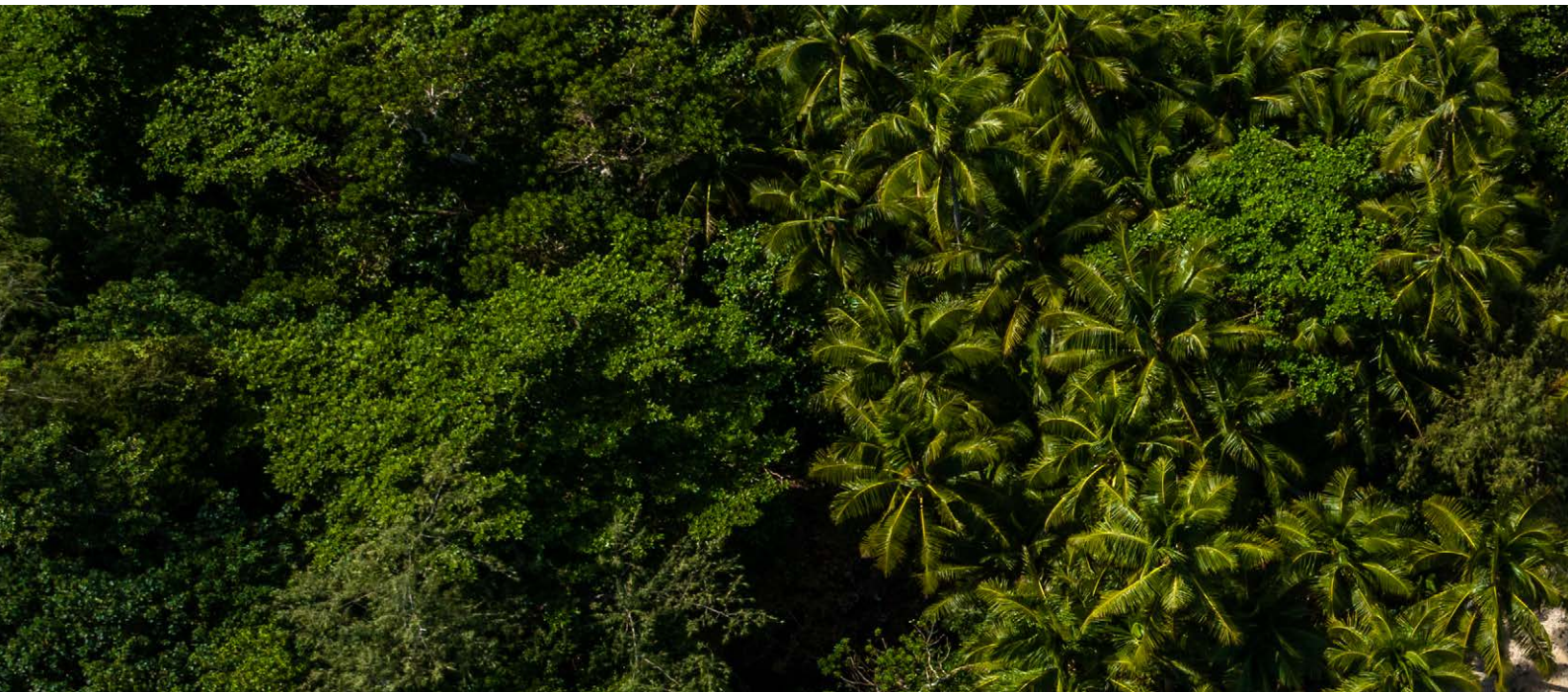
[14] https://climateknowledgeportal.worldbank.org/country/papua-new-guinea/climate-data-projections

[15] https://climateknowledgeportal.worldbank.org/sites/default/files/country-profiles/15871-WB_Papua%20New%20Guinea%20Country%20Profile-WEB.pdf

[16] World Food Programme, 2019. The Impact of Drought related to El Nino, Papua New Guinea. Available at: file:///C:/Users/BrownLy/Downloads/20190410_PNG_Drought_Monitoring.pdf

[17] McVicar, T.R. and Bierwirth, P.N., 2001. Rapidly assessing the 1997 drought in Papua New Guinea using composite AVHRR imagery. International Journal of Remote Sensing, 22(11), pp.2109-2128.

[18] Available at: http://www.pngmet.gov.pg/



The various datasets cited above for rainfall are also relevant for drought monitoring and evaluation, particularly when converted to an index designed to capture drought. Additionally, other optical and microwave satellite-based sensors are used to generate other drought monitoring products such as Standardised Precipitation Index (SPI), Normalised Difference Vegetation Index (NDVI) / Enhanced Vegetation Index (EVI)[19] and Evapotranspiration (ET).[20]

Landslide

PNG has high landslide risk due to a combination of factors including steep terrain, geo-tectonics and tropical weathering leading to high landslide potential, and high and intense rainfall, and earthquakes providing abundant trigger opportunities. It has been estimated that as much as one-tenth of the world's annual death toll from landslides occurs in PNG.[21] A study by Robbins and Petterson found that there is a strong climatic control on landslide-triggering events and that an estimated 61% of landslides in the PNG landslide inventory are initiated by rainfall related triggers.[22] Furthermore, the year-to-year variability in the annual occurrence of landslide events has been related to the El Niño Southern Oscillation (ENSO) and mesoscale rainfall variability. However, PNG lacks adequate baseline data for landslides, making future hazard and risk assessment difficult. Earthquake triggering of landslides is an important component of the hazard potential of landslides in PNG: for example, after a 7.5 magnitude earthquake in 2018, more than 10,000 landslides were triggered, directly or indirectly affecting 544,000 people.

Landslides cause significant socio-economic impacts on PNG communities, and it is anticipated that with increasing development of infrastructure and the increasing number of building and road networks in high-risk areas, landslide risk will remain high. Landslides also have the potential to cause large scale disruption to the energy industry in PNG. For example, a newly established natural gas pipeline that runs through the southern highlands of PNG is vulnerable to landslides. Gas and oil leaks due to infrastructure damage could endanger the environment and biodiversity.[23]

Tropical Cyclones

Figure 4 shows that Papua New Guinea has been impacted by cyclones in the past. The Madang province in the north is not prone to cyclones based on historical data from 1970-present, and nor is it foreseen to increase in future projections. The low risk from tropical cyclones is due to all of Madang being within 6 degrees of the equator, and the great difficulty in any tropical cyclones being sustained that close to the equator due to low to non-existent Coriolis effect. The northern coastal areas, however, may be partly affected with an increase in wind speed, cloud, and waves from tropical cyclones which pass by PNG. These may have a significant impact in the form of coastal flooding and inundation of low-lying islands.

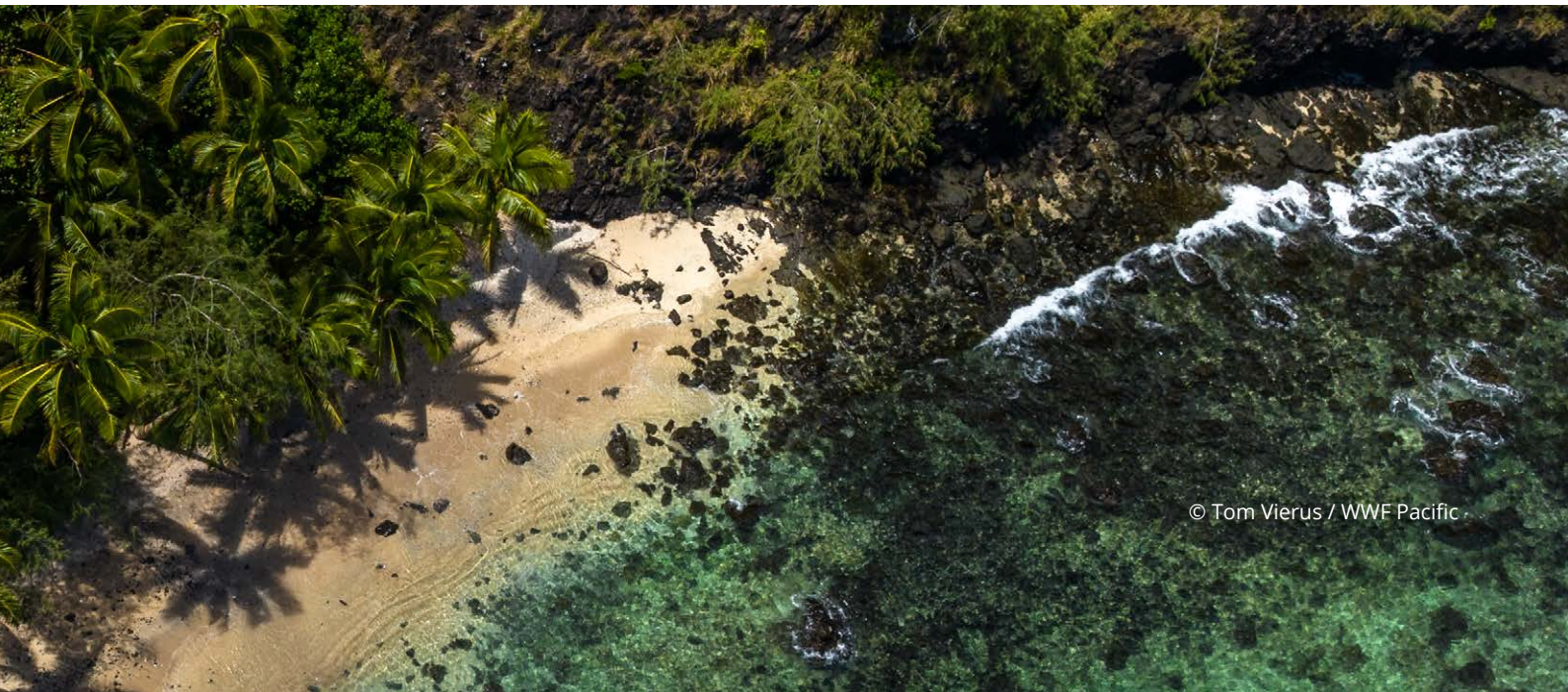
[19] https://climatedataguide.ucar.edu/climate-data/ndvi-and-evi-vegetation-indices-modis

[20] e.g., NASA MODIS MOD16A2 operational product

[21] Greenbaum et al., 1995. Rapid Methods of Landslide Hazard Mapping: Papua New Guinea Case Study. Available at: https://nora.nerc.ac.uk/id/eprint/9967/1/WC95027.pdfAvaiu

[22] Robbins, J.C. and Petterson, M.G., 2015. Landslide inventory development in a data sparse region: spatial and temporal characteristics of landslides in Papua New Guinea. Natural Hazards and Earth System Sciences Discussions, 3(8), pp.4871-4917.

[23] UNDRR, 2019. Disaster Risk Reduction in Papua New Guinea. Available at: https://www.preventionweb.net/files/68266_682309pngdrm-statusreport.pdf



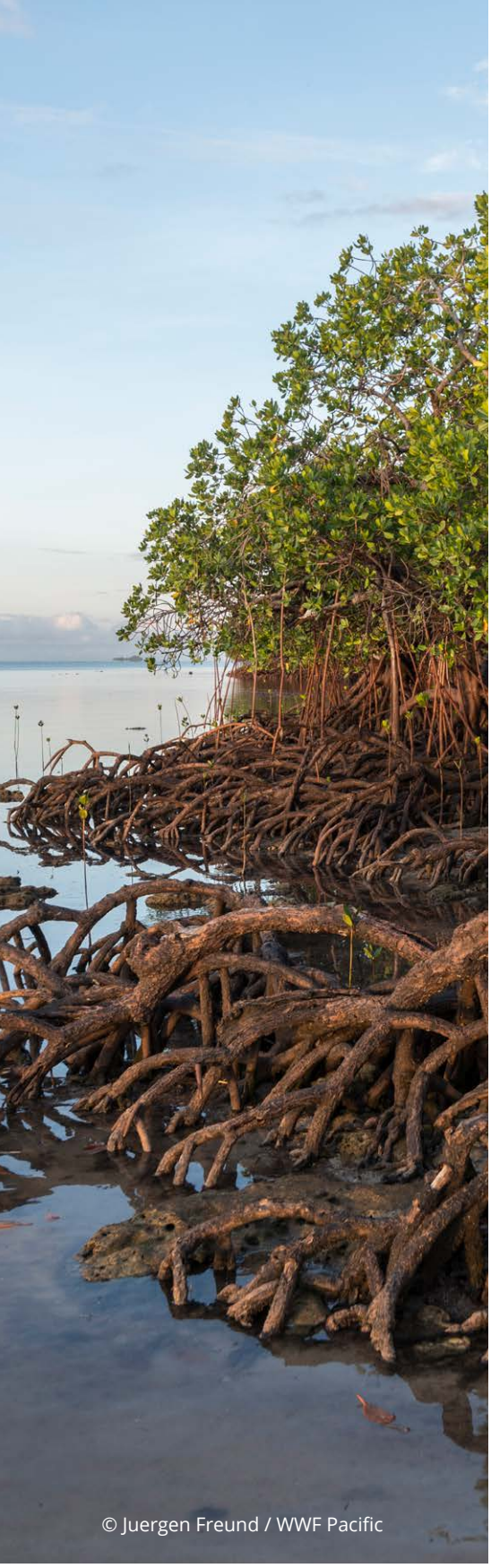
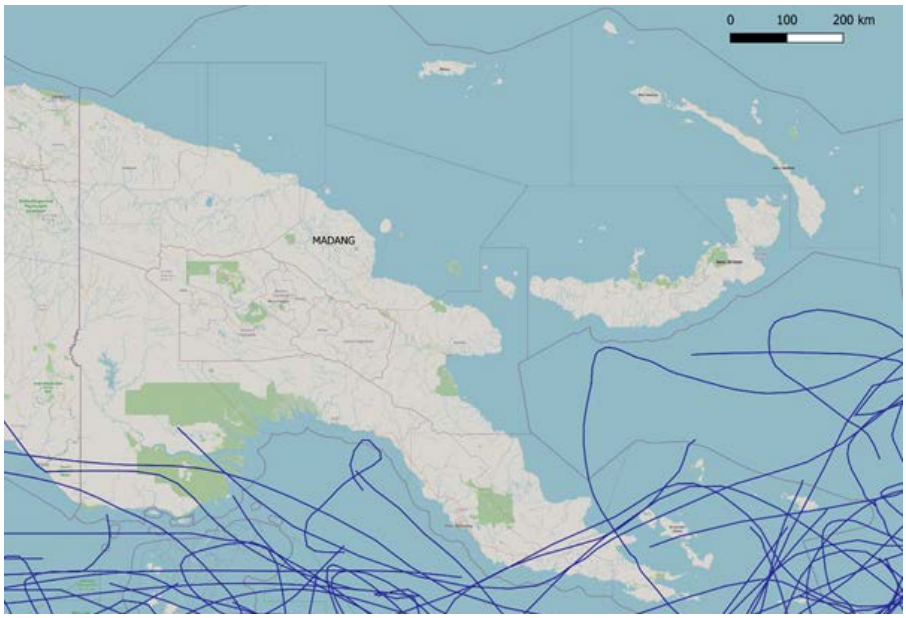

© Juergen Freund / WWF Pacific

Figure 4: Historical tropical cyclone tracks, 1970-present



Tropical cyclone data is readily available. Historical storm tracks are available from IBTrACS going back to 1897 and can also be visualised on NOAA's Historical Hurricane Tracks tool.

Disease

As the largest nation in the Pacific by land mass and population, PNG's incredibly diverse terrain and widely scattered communities has posed continual challenges in resources for health delivery. With barely one doctor per 10,000 people, the provinces furthest from Port Moresby have the highest levels of early childhood mortality and low levels of immunisation.[24] Health concerns in PNG are dominated by communicable disease such as pneumonia, tuberculosis (TB), malaria and diarrhoeal diseases. Before 2014, steady decline in malaria cases had been observed, but by 2019 the number of cases had increased 10-fold from 50,309 to 646,648 in a five year period.[25] Similarly, TB has seen an increase due to declining treatment success rates. HIV prevalence in PNG has remained below 1%, after decreasing by over 25% since 2001.[10]

Papua New Guinea's hot, tropical climate and large bodies of stagnant water provide conducive breeding grounds for infected mosquitoes, allowing malaria to be easily spread. Sea level rise and flooding are a significant concern for waterborne diseases. Faeco-orally transmitted diseases have been correlated with high precipitation and flooding in areas where sanitation and access to safe water are lacking and thus exposure to diseases high.[26] The rise in extreme climatic events will induce population displacement, which creates a conducive environment to the spread of TB and the development of active TB, and disrupts TB diagnosis and treatment services.[27]

[24] World Health Organization, 2018. Country Cooperation Strategy at a glance, Papua New Guinea. Available at:https://apps.who.int/iris/bitstream/handle/10665/136819/ccsbrief_png_en.pdf;sequence=1#:~:text=The%20burden%20of%20disease%20in%20Papua%20New%20Guinea,diseases%2C%20but%20the%20prevalence%20of%20noncommunicable%20diseases%20is

[25] World Economic Forum, 2021. Papua New Guinea is battling the World's oldest pandemic: malaria. How can it get back on track? Available at: https://www.weforum.org/agenda/2021/09/papua-new-guinea-malaria/

[26] UNDRR, 2019. Disaster Risk Reduction in Papua New Guinea. Available at: https://www.preventionweb.net/files/68266_682309pngdrmstatusreport.pdf

[27] Maharjan, B., Gopali, R.S. and Zhang, Y., 2021. A scoping review on climate change and tuberculosis. International Journal of Biometeorology, 65(10), pp.1579-1595.

[28] Stephanie McLennan and Rachel LaFortune, "Papua New Guinea's Rapid Tides Expose Climate Risks", Human Rights Watch, 20 December 2021, https://www.hrw. org/news/2021/12/20/papua-new-guineas-rapid-tidesexpose-climate-risks

Rising Sea Levels

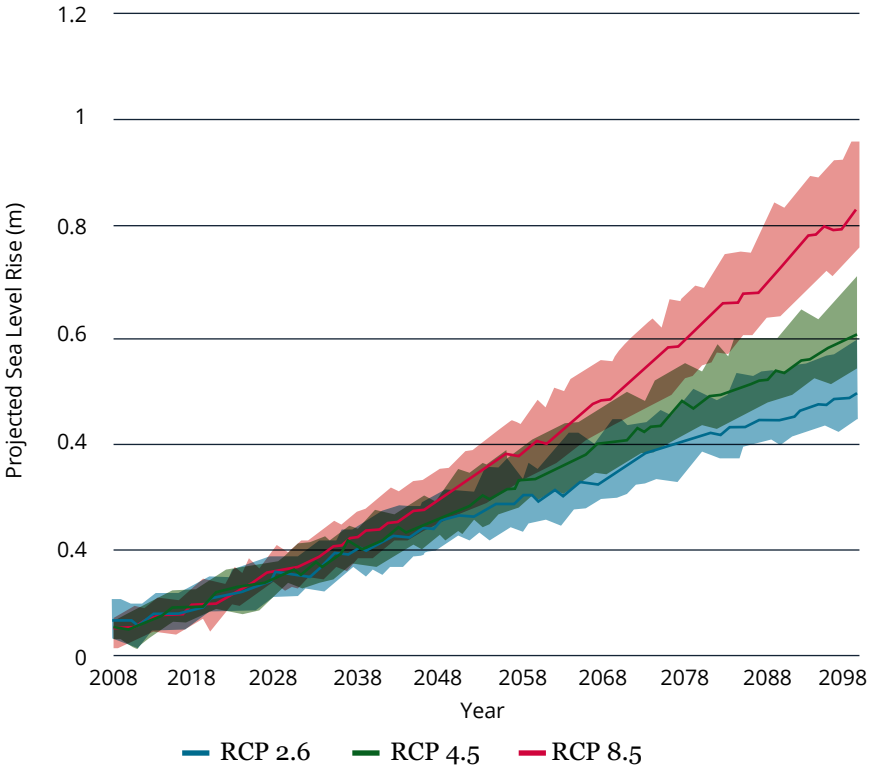
As atmospheric temperatures rise, ocean water warms and expands and continental ice melts, causing the sea level to rise. Sea level rise (Figure 5) is a serious consequence of climate change for PNG; satellite altimeters since 1993 have registered a sea level rise of approximately 7 mm per year, which is more than double the global average of 3.2 mm per year. The sea level rise under the RCP 8.5 high emissions scenario and relative to pre-industrial levels could reach 15 cm by 2030, signifying that flooding and storm surge will also increase. Rising sea levels will threaten coastal communities' infrastructure, industrial facilities and ground water resources.

PNG's National Disaster Centre (NDC) has warned of severe sea swells called "king tides": these tides can reach in excess of 2.5 m along the coast of PNG. In 2008, a large "king tide" occurred affecting an estimated 38,000 people and destroying or damaging 2,000 houses. Again in 2021, the UN Office for the Coordination of Humanitarian Affairs (OCHA) reported unusually high tides affecting at least 53,000 people. Sea level rise and greater intensity of storms are likely to contribute to loss of biodiversity as a result of the impacts.[28]

Rising Sea Temperatures/ Ocean Acidification

Average Sea Surface Temperature (SST) in the Pacific has increased by approximately 0.7°C since 1900 and is expected to continue to increase to 1.2-1.6°C by 2050 and 2.2-2.7°C by 2100 under the RCP 8.5 emissions scenario.

Figure 4: World Bank projected sea level rise for coastal Papua New Guinea relative to 1980-2005 average under RCP 2.6, RCP 4.5 And RCP 8.5 Emissions scenario.[29]



In the context of fisheries, there is high confidence that ocean warming will reduce the global maximum catch potential, and some areas such as the Pacific will experience three times the decrease in catch potential than the global average by 2100 under an RCP 8.5 scenario, with serious consequences for fisheries-based livelihoods.[30]

Atmospheric carbon dioxide concentrations are nearly 40% above pre-industrial levels and are likely to reach 100% of pre-industrial levels before stabilising, without immediate and dramatic emissions reductions. Ocean acidification occurs because the ocean absorbs approximately one third of the carbon dioxide (CO_2) released, and the absorption of CO_2 causes the ocean's pH to decrease.

Such changes in carbonate chemistry of the oceans can have dramatic effects on marine organisms and coral reefs. Based on the RCP 8.5 scenario the Pacific pH is projected to decrease by a further 0.15 units into the 2040-2060 period (figure 6).[31] Ocean saturation levels above 4 are optimal for coral calcification, and calcification of coral is vital for coral growth and important for a healthy reed ecosystem. As predictions suggest saturation levels between 3 and 3.5, model projections predict the entire tropical Pacific will have shifted to sub-optimal conditions. This risk will only increase, projections for 2100 suggest that even with good management, live coral cover will decrease by >90% relative to 2010.

[29] World Bank, Climate change Knowledge Portal. Available at: https://climateknowledgeportal.worldbank.org/country/papua-new-guinea/impacts-sea-level-rise [Accessed on 15th July 2022]

[30] IPCC 2019, cited in Holbrook et al

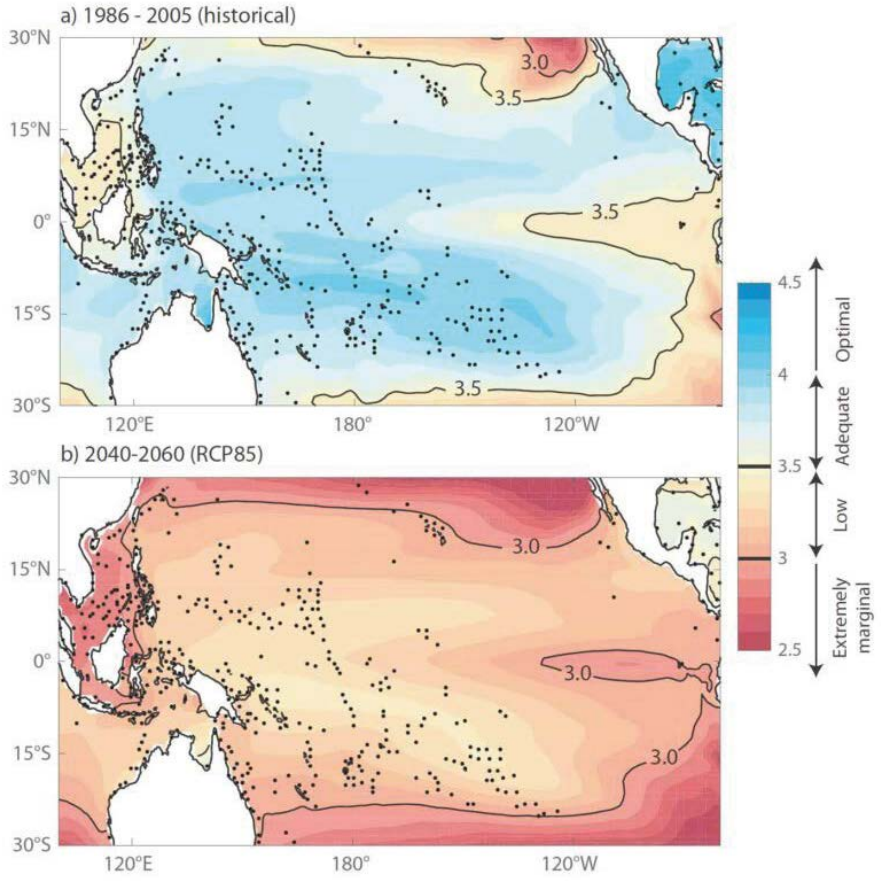
[31] Johnson, Bell and Gupta, 2015. Papua New Guinea ocean acidification vulnerability assessment. [online] Available at: https://png-data.sprep.org/resource/pacific-islands-ocean-acidification-vulnerability-assessment-0 [Accessed 15 Jul. 2022].

Apart from damaging habitats, research also suggests that ocean acidification alters fish behaviour, and changes the pH of the fish's blood in a condition called acidosis, which leads to changes in the fish's metabolism.[32] More research is needed to understand exactly how ocean acidification impacts fish, but research to date indicates that ocean acidification could pose a direct threat to fish survival and therefore to fish stocks. Other ecosystems such as seagrass meadows and mangroves are actually expected to benefit from increased CO2 and are therefore not vulnerable to ocean acidification.[33]

There is a lack of ocean acidification monitoring data in the region, however, with only three ocean acidification monitoring buoys established as of 2019 by the Pacific Island Countries Ocean Acidification Observation and Response Network – in Palau, the Federated States of Micronesia and Samoa. Although more are planned in the region, none are immediately expected in PNG. Predictions of ocean pH under different climate scenarios are reliable, however, due to a robust understanding of the chemistry of how CO2 affects ocean pH.

Sea temperature data is more readily accessible from the SEAFRAME gauge at Lombrum (as part of the Pacific Sea Level and Climate Monitoring Project) and there are a number of other sources such as NOAA's Coral Reef Watch, NOAA's daily OISST and NASA's GISTEMP.

Figure 5: Lenton et al. Show the modelled changes to aragonite saturation as part of a project using the RCP 8.5 Emissions scenario. Black dots show the location of coral reefs.[34]



[32] https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification#:~:text=While%20fish%20don't%20have,blood%2C%20a%20condition%20called%20acidosis.

[33] SPREP Pacific Islands

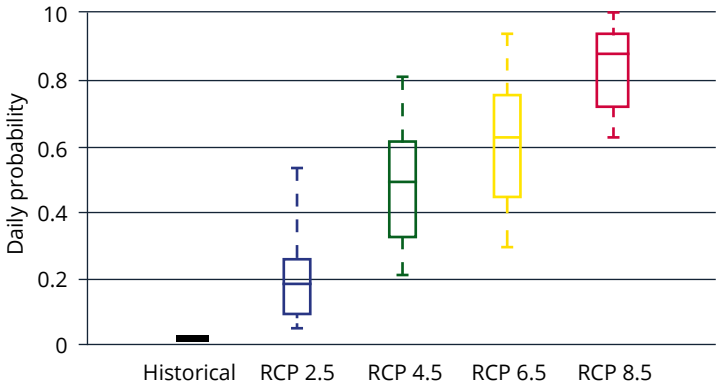
[34] Lenton, A. and McInnes, K.L., 2015. Marine projections of warming and ocean acidification in the Australasian region. Australian Meteorological and Oceanographic Journal, 65(1), pp.S1-S28. In press.

Temperature Changes

Papua New Guinea repeatedly experiences high maximum air temperatures, with an average monthly maximum of around 31°C and an average November maximum of 32°C.[35] An analysis conducted by the World Bank found that by 2090 PNG will see a considerable increase in the likelihood of heatwaves under all emissions and climate change scenarios (Figure 7). Based on this information, PNG may transition to a chronically heat-stressed environment. Under the three lowest emissions pathways, there will be an increase in days per year with maximum temperature reaching 35°C of between 9 and 26. This presents a potential health hazard to PNG's population.

Figure 6: The World Bank's projected change in the probability of observing a heat wave in PNG for the period 2080-2099.[36] The figure shows 4 different emissions pathways.

A 'Heat Wave' is defined as a period of 3 or more days where daily temperature is above the long-term 95th percentile of daily mean temperature.



[35] World Bank Group, 2021. Climate Risk Country Profile, Papua New Guinea. Available at: https://reliefweb.int/report/papua-new-guinea/papua-new-guinea-storm-surge-still-concern-support-trackhttps://climateknowledgeportal.worldbank.org/sites/default/files/country-profiles/15871-WB_Papua%20New%20Guinea%20Country%20Profile-WEB.pdf

[36] World Bank Group, 2021. Climate Risk Country Profile, Papua New Guinea. Available at: https://reliefweb.int/report/papua-new-guinea/papua-new-guinea-storm-surge-still-concern-support-trackhttps://climateknowledgeportal.worldbank.org/sites/default/files/country-profiles/15871-WB_Papua%20New%20Guinea%20Country%20Profile-WEB.pdf

Non-Climate-Related Hazards

Although this project focuses on hazards that are related to climate change, it is worth also briefly mentioning Papua New Guinea's exposure to other hazards such as earthquake.

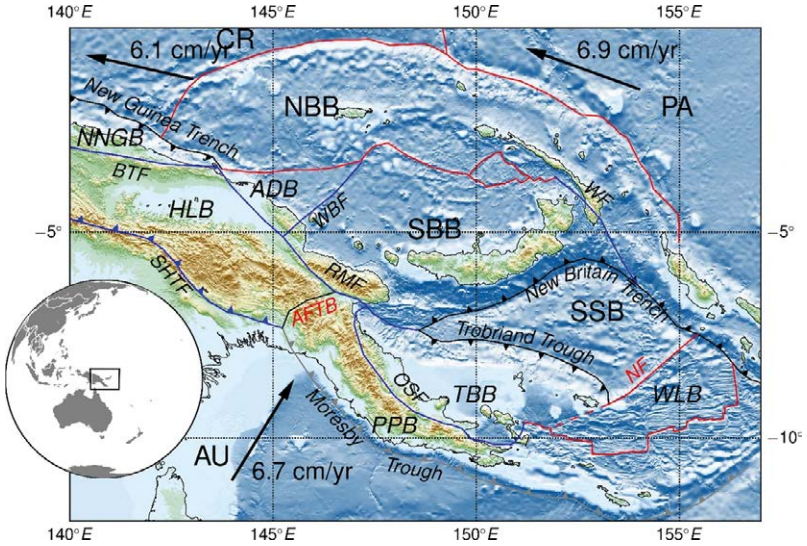
Earthquake/seismic risk

Papua New Guinea is situated along one segment of the Pacific "ring of fire", which aligns with the boundaries of the tectonic plates (Figure 8). These boundaries are extremely active seismic zones capable of generating high magnitude earthquakes. A recent example was on the 26th of February 2018, when a magnitude 7.5 earthquake struck PNG. At least 170 aftershocks were recorded including one of 6.7 magnitude. Approximately 544,000 people were affected, and 34,100 people were displaced and living in informal camps.[37] Earthquake hazard and earthquake risk mitigation is vital in PNG where the chances of such a disastrous event occurring are high and a single event could collapse the economy.

Although seismicity poses a significant risk to PNG, building codes are based on earthquake hazard maps created in 1982.[38] The maps used poor quality data, meaning that buildings and infrastructure near active faults may be even more vulnerable to earthquakes than according to the maps.

At different levels of government, funding for earthquake monitoring and research is insufficient, in part due to the country's level of economic development.

Figure 7: Tectonic setting of PNG. The boundaries of major tectonic plates (AU—Australian, PA—Pacific, CR—Caroline) and microplates or blocks (NBB—North Bismark, SBB—South Bismark, SSB—Solomon Sea, WLB—Woodlark, TBB—Trobriand, HLB—Highlands, PPB—Papuan Peninsula, ADB—Adelbert). The boundaries that are colored blue or black are considered as fault sources for the seismic hazard analysis, while boundaries colored red and gray are not. Toothed boundaries indicate convergence, with black-toothed boundaries indicating active subduction, gray uncertain activity, and blue active continental convergence. Microplate boundaries considered in the hazard analysis are: BTF—Bewani–Torricelli, SHTF—Southern Highlands Thrust, OSF—Owen Stanley, WBF—West Bismark, RMF—Ramu–Markham, WF—Weitin. Arrows show the direction of movement of the corresponding major plate (AU,CR and PA) in the ITRF2008 reference frame[40]



PNG seismic monitoring is carried out by the Geohazards Management Division of the Department of Mineral Policy and Geohazards Management.[39]

Volcanic Eruptions

Madang is home to active volcano Manam (Figure 11), located 13 km off the northern coast of New Guinea, in New Bogia. Manam is a stratovolcano, a type that is characteristic of explosive eruptions. Since 1616, the volcano has produced frequent mild-moderate explosive eruptions, often producing ash plumes, and sometimes pyroclastic flows. Madam is one of six of PNG's volcanoes categorised as high risk.

The island has also been identified as one of several volcanoes where an eruption or flank collapse could produce a tsunami.

In 2004, an extensive series of eruptions resulted in more than 10,000 people being displaced. Since then, the volcano has remained active: on the 20th of October 2021 the volcano started emitting ash, steam and debris affecting a total of 4,648 people.[41] Eruptions before 2015 are listed in Table 3 on the following page.

The volcano is monitored on the ground by the Rabaul Volcanological Observatory.[43]

[37] WHO, 2018. Papua New Guinea Earthquake: Situation Report No. 2 28 March 2018. Available at: https://www.who.int/docs/default-source/wpro---documents/emergency/png-earthquake/20180328-png-quake-sitrep2.pdf?sfvrsn=48ace0bf_0

[38] The Seismic Hazard Map of Papua New Guinea: Seismotectonics, Probabilistic Ground Motions and the Building Code. Available at: https://www.ga.gov.au/news-events/events/public-talks/public-talks-archive/the-new-seismic-hazard-map-of-png

[39] Available at https://webdev.datec.net.pg/geohazards/

[40] Altamimi Z, Collilieux X, Métivier L (2011) ITRF2008: an improved solution of the international terrestrial reference frame. J Geodesy 85(8):457–473 https://link.springer.com/article/10.1007/s10518-020-00966-1

[41] Zorn, E.U., Orynbaikyzy, A., Plank, S., Babeyko, A., Darmawan, H., Robbany, I.F. and Walter, T.R., 2022. Identification and ranking of volcanic tsunami hazard sources in Southeast Asia. EGUsphere, pp.1-38.

Table 3: Major eruptions of the Manam volcano.[42] (Note: volcano monitoring was absent in early years and there is no consensus of what defined a "major eruption", either in terms of explosiveness or human impacts, thus this table is indicative.)

Date
1904
1917
1919/1920
1936/1938
1946/1947
1957/1958
1960
1974/1975
1992/1994
1996
2001
2004/2005
2010
2015

Tsunamis

There is a potential for tsunami devastation such as the one that occurred in 1998, in both the southern and northern borders of Madang. Before the 1998 tsunami there had been no catastrophic tsunami on the coast of PNG for 67 years, too long ago for the memory to be retained, and no public awareness campaigns had been conducted in years.

The 1998 tsunami was most likely caused by a submarine slump or landslide caused by a magnitude 7.1 earthquake.[44]

The tsunami reached over 10m in height, causing 2,200 deaths and forcing 10,000 people to relocate.

The Geohazards Management Division (GMD) provides early warning of earthquakes, tsunamis, volcanic eruptions, landslides and mass erosion events in PNG.

Overview of Historic Events and Impacts

In this section, an overview of historical climate-related disasters is presented based on available information. This information does not include chronic climate impacts we have highlighted in the previous section, such as ocean acidification, and we also note that historical impacts, particularly of a short and incomplete record, are not necessarily a good indicator of future impacts, particularly when climate change is taken into account. During this project, we will gather further information for hazards selected for analysis.

PNG is vulnerable to several hazards, some of which are expected to increase in frequency, magnitude, and intensity due to climate change. The ENSO phenomenon has already been observed to have an increasing negative effect on PNG's climate hazards and increasing the intensity of floods and droughts.

Flooding is the climate hazard that has impacted the most people in PNG (Figure 15). According to the Global Facility for Disaster Risk Reduction (GFDRR), potentially damaging and life-threatening floods are expected to occur at least once every 10 years.[45]

The Pacific Catastrophe Risk Insurance Company (PCRIC) catastrophe risk model, which includes loss of damage for infrastructure assets, major crops as well as economic values, estimated a replacement value of USD 49.2 billion.

When these events occur, many people are displaced and face similar challenges to those that flee conflict zones. Many lose their homes, assets, income, and they face insecurity, reduced access to basic needs and services such as water, food, healthcare and education and disrupted social networks. Internal displacement in PNG is widespread and exacerbated by tribal conflict. The UN International Organization for Migration (IOM) found that the highest percentage of internally displaced persons, 43%, are located in the PNG highlands, and 72% are displaced by climate and geophysical hazards.[46]

[42] Connel and Lutkehaus, 2016. Another Manam? The forced migration of the population of Manam Island, Papua New Guinea, due to volcanic eruptions 2004-2005. Available at: https://publications.iom.int/books/another-manam-forced-migration-population-manam-island-papua-new-guinea-due-volcanic

[43] Available at https://webdev.datec.net.pg/geohazards/

[44] Davies et al., 2019. Past major tsunamis and level of tsunami risk om the Aitape coast of Papua New Guinea. Available at: https://link.springer.com/article/10.1007/s11069-019-03585-5

[45] https://thinkhazard.org/en/report/192-papua-new-guinea/FL

[46] https://crisisresponse.iom.int/response/papua-new-guinea-crisis-response-plan-2021

Figure 9: Visual display of the average annual occurrence of each disaster for 1980-2020. World Bank Climate Change Knowledge Portal [47]

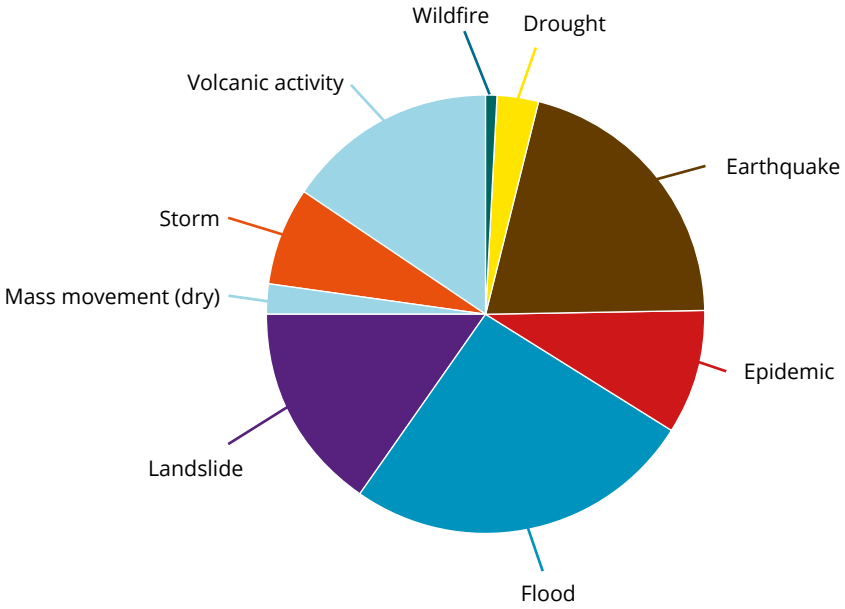
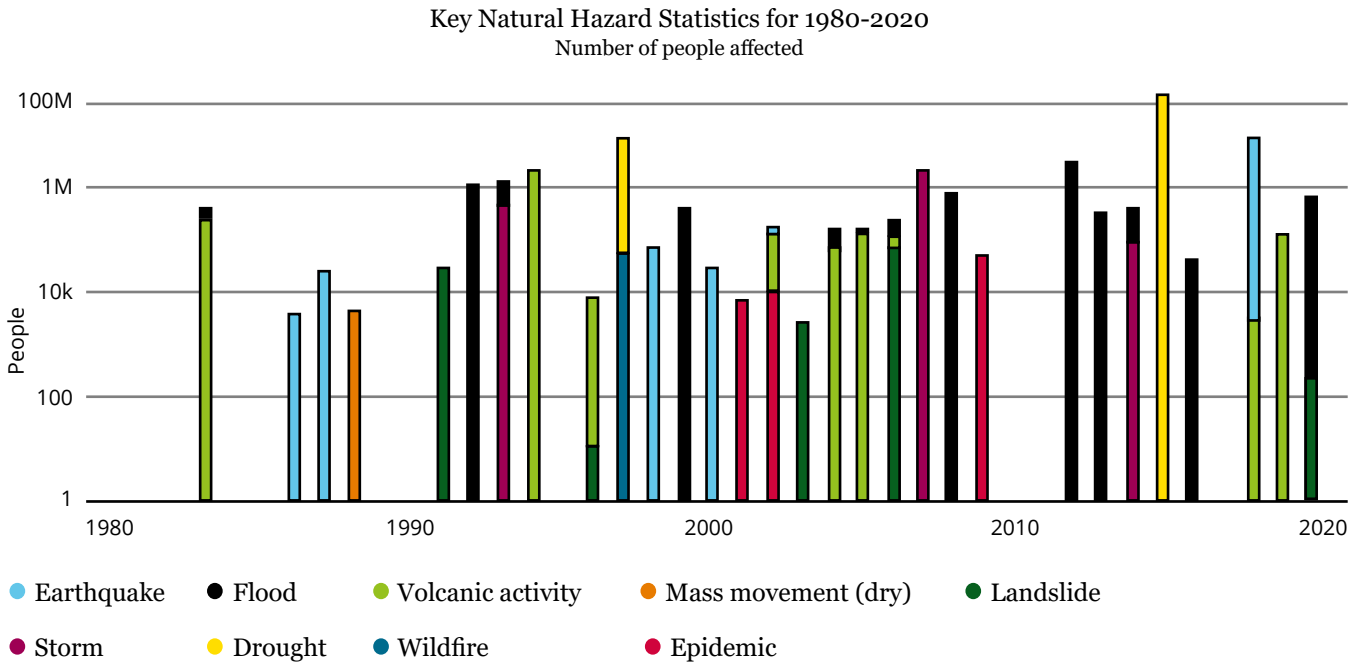


Figure 10: Disasters that have occurred in png between 1980-2020 and the associated number of people affected. World Bank Climate Change Knowledge Portal [48]



[47] Available at: https://climateknowledgeportal.worldbank.org/country/papua-new-guinea/vulnerability
[48] Available at: https://climateknowledgeportal.worldbank.org/country/papua-new-guinea/vulnerability

Exposure refers to the people and economic assets that become concentrated in a hazard-prone area. Formal analysis of the exposure and vulnerability of Pacific Islands is currently lacking, with limited data availability, approaches that are too broad, or data that is misleading. One recent study uses a mixture of census data and global datasets SEDAC-CIESIN GPWv4 and the Oak Ridge National Laboratory LandScan to estimate that, of PNG's total population, 30% live within 10km of the coast, and 8% within 1km of the coast. The proportion of the population in PNG living close to the coast is key in understanding its exposure to climate change and ocean-related threats.

The table on the right lays out key information relevant to understanding the exposure of people and assets in PNG. On top of these, it is also important to consider natural assets, which are often left out of countries' balance sheets but are also crucial to the economy. The below table provides information on the marine natural assets of PNG.

Table 4: Summary of exposure in PNG as of 2010, PCRAFI[49], and complemented by World Bank open data.

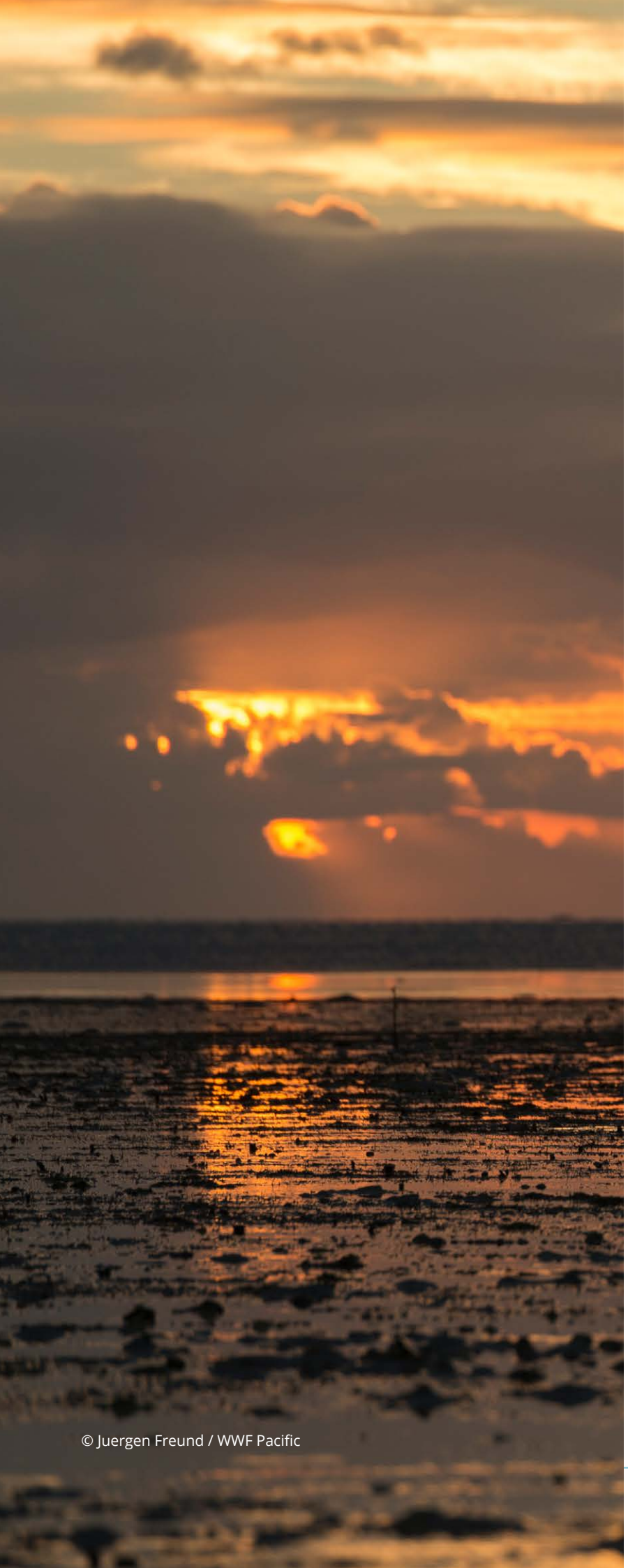
General Information:	
Total population	9,119,005 (2021), 51% M 49% F
GDP per Capita (USD)	2,655.17 (2022)
Total GDP (million USD)	38,000,000,000
Asset Counts:	
Residential Buildings	2,261,485
Public Buildings	43,258
Commercial, Industrial, and other buildings	88,536
All buildings	2,393,279
Hectares of major crops:	1,350,990
Cost of replacing assets (Million USD):	
Buildings	39,509
Infrastructure	6,639
Crops	3,061
Total	**49,209**
Government revenue and expenditure:	
Total Government Revenue	
Million USD	3,971,631,160
(% GDP)	14.7
Total Government Expenditure	
(Million USD)	5,673,758,800
(% GDP)	21.3

Table 5: Basic marine data. CEPA and national coordination committee for the Papua New Guinea marine program and the coral triangle initiative on coral reefs, fisheries and food security[50]

	National	Madang
Exclusive economic zone (EEZ)	3,120,000 km2	
Length of coastline	20,530 km	867 km
Coastal and island habitat.	46,000 km2	
Coastal and island population and % of total PNG population	2.2 million (24%)	493,906
Coastal villages (851,200 people)	1,200 villages	
Coral reef	14,535 km^2	52 km^2
Proportion under protection	4%	
Mangrove total area	5,734 km^2	12 km^2
Protected area 2015	13.73%	
Seagrass area	4,504,132	

[49] Pacific Catastrophe Risk Assessment and Financing Initiative, https://pcric.org/wp-content/uploads/2022/03/PNG-1.pdf

[50] Conservation and Environment Protection Authority (CEPA) and National Coordination Committee for the Papua New Guinea Marine Program and the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security. Papua New Guinea Marine Program on Coral Reefs, Fisheries and Food Security, 2019-2023



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Natural Assets

Containing 7% of the world's biodiversity, Papua New Guinea is classified as one of the seventeen "megadiverse" countries in the world. It is located within the Coral Triangle, a region recognized for its coral reef biodiversity. Overall, coral reefs cover 14,535 km2 of which 4% are protected. The North coast, including Madang, are dominated by fringing and patch reefs. A report by the Madang Locally Managed Marine Area (LMMA) Network prepared by Wetlands International assessed the diversity of coral reef fishes as an indication of the biodiversity of the coral reefs in Madang's Marine Area Network. The Madang Lagoon is estimated to contain 700 species of coral and 1,000+ species of reef fish. This biodiversity is fundamental to the health of the society, economy, and culture of a predominantly rural population (85%). Coral reef fisheries are a vital source of food and income for these communities, and also provide a physical barrier to ocean swells and storm surges, protecting the shoreline against erosion. This biodiversity is under threat from major extractive industry (forestry, agriculture and mining), overfishing, unsustainable fishing practices, land-based sources of marine pollution, coastal habitat conversion and a rapidly growing human population.[53]

Mangroves are widespread around the coastal regions of PNG, and particularly extensive around the deltas of major rivers. Mangroves have close-knit lattices of aerial roots that stabilise mud and silt sediment. For this reason, mangrove planting has been undertaken by most organizations as a cost-effective adaptation measure for

[53] https://www.cbd.int/doc/world/pg/pg-nr-05-en.pdf

coastal protection against erosion from storms and high waves. The Climate Change and Development Authority (CCDA) set up the "Million Mangroves" project that aims to facilitate the planting of millions of mangrove trees. Substantial damage or loss of mangroves can result in significant changes to coastal erosion: changes in deposition along coastlines can have profound effects on the coastal ecosystem, the provision of ecosystem services, and the stability and use of coastal infrastructure. The protected waters inside the mangroves provide rich habitats for many marine and estuarine species, and several commercially important PNG fisheries. Mangroves are susceptible to changes in coastal sedimentation flow: if the rate of sedimentation increases, the roots can suffocate leading to cessation of growth and ultimately, death of the trees. If sedimentation rates decrease leading to insufficient sediment and organic matter entering the system, the growth of the mangrove can be limited; loss of sediment can expose the roots making them susceptible to damage and disease and ultimately risk structural failure as their anchorage in a thinner soil becomes less secure.[54]

Fisheries

For many Pacific Island communities, including PNG, coral reefs and mangroves underpin important sources of protein and income that people are reliant on and are unable to obtain elsewhere. This is reflected in the national fish consumption (13kg per person, but 53kg in coastal communities[55]), and coastal fishing representing 85.8% of people's main or second source of income.[16]

The fishing industry in PNG is categorised by the National Fisheries Authority (NFA) as "coastal commercial" or "offshore". Coastal communities consider fish as an integral part of society, particularly as food, as a trade item for the traditional bartering systems and as a commodity to earn cash. Invertebrates are usually caught by gleaning on reef flats or free diving in deeper water.[56] In contrast, reef fish are collected by way of handlines, gill nets, hand spears or traps. Since 2019, sea cucumbers have been over-exploited and trochus are considered to be at their maximum sustainability yields.[57]

Offshore fishing consists of the industrial tuna fishery, which is composed of local PNG vessels, foreign-owned but locally-based vessels and licensed foreign-flagged vessels who can fish within PNG's Exclusive Economic Zone (EEZ). Foreign vessels have been exploiting PNG's tuna stocks since 1970s. During this time, rural communities were also involved in commercial reef fisheries with support from the government in the form of training programmes and donor-funded projects which aimed to develop infrastructure and fishing techniques. Many of these initiatives were poorly implemented, lacking consideration of the socio-economic dynamics of rural communities.35 Additionally, there are now concerns over the sustainability of the tuna fishery, with stocks of two of the three main tuna species (Yellowfin and bigeye) considered fully exploited.[58] Inshore fish populations are also declining due to ballast water and oils spills from larger ships and engine noise, as well as waste from canneries and mines.

The Fisheries Management Act 1998 makes the NFA responsible for the management and development of the fisheries sector. The NFA implements Papua New Guinea's Fisheries Strategic Plan 2021–2030[59], which has a strong focus on increasing production volume of fish and revenue through incentivising foreign investment and increasing domestic fish processing capabilities. The Plan also recognises the need to abide by international minimum standards to maintain exportability and sustain fish stocks. It aims to increase food security by increasing subsistence fishing, and the NFA has established a commercial fishing entity, which allows it to pay dividends to the government and thus contribute to the government budget. Due to these commercial interests and the fact the NFA's expenses are largely supported by the tuna industry, Fisheries planning and policy is often focused on tuna, and PNG's 6th National Report to the CBD[60] recognises the need for the NFA to increase attention paid to coastal and subsistence fisheries. The report also notes that ecosystems have not been systematically defined and mapped across Papua New Guinea, leading to difficulties in managing and monitoring ecosystems.

The NFA is also in charge of implementing the Pacific Marine Industrial Zone project, a large-scale project supported by loans from China which aims to transform Madang into a Special Economic Zone with a fishing port and processing hub, the largest in the southern hemisphere.

[54] National CTI Coordinating Committee pf Papua New Guinea, 2012. State of the Coral Reefs of Papua New Guinea Coral Triangle Marine Resources: their Statues, Economies, and Management. Available at: https://png-data.sprep.org/dataset/coral-reefs-0
[55] ADB, 2014. State of the Coral Triangle: Papua New Guinea. Available at: https://www.adb.org/sites/default/files/publication/42413/state-coral-triangle-papua-new-guinea.pdf
[56] Kronen et al., 2008.
[57] Teh et al., 2014. Reconstructing Papua New Guinea's Marine Fisheries Catch 1950-2010.
[58] National Fisheries Authority, https://www.fisheries.gov.pg/challenges-and-issues
[59] https://faolex.fao.org/docs/pdf/png205423.pdf
[60] https://png-data.sprep.org/dataset/cbd-national-report

The project has been subject to lengthy delays over multiple years due to concerns. Should the project be implemented, this will have significant implications for the Madang fishing communities' ability to continue their lifestyle.

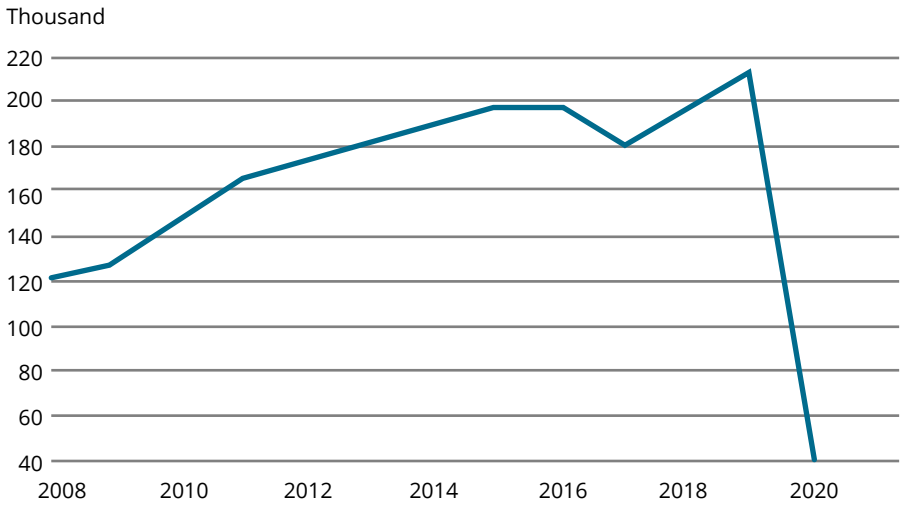
Tourism

Tourism in PNG remains underdeveloped. Data from the IFC led International Visitor Survey (IVS) shows that PNG has the smallest number of holiday visitors, compared to neighbouring countries. Tourists comprised around 50% of about 181,840 arrivals in 2017 while, by comparison, in neighbouring countries it is around 75% (Fiji and Vanuatu).[61] Despite the government increasing its tourism budget by three-fold to K6 million (USD 1,704,545) to K13 million (USD 3,693,181) for the first time in 2004 it remains largely unfragmented. The only segment of the tourism sector that is developed is the diving sector, which accounts for approximately 68% of the tourists visiting PNG. However, The Papua New Guinea Tourism Sector Development Plan 2022-2026 outlines the plan to develop nature and culturally based tourism that could provide considerable revenue to PNG.[62]

Country-Level Vulnerability Profile

In the disaster risk community, vulnerability is often defined as a "set of conditions and processes resulting from physical, social and economic factors, which increase the susceptibility of a community to the impact of the hazard".[64] Self-reliance and low resilience of communities and households against climate and disaster impacts across PNG create numerous vulnerabilities stemming from socioeconomic factors.

Figure 11: International tourism, number of arrivals - Papua New Guinea.[63]



For example, disasters like flooding, sea level rise, volcanic eruptions and earthquakes typically result in large numbers of displaced people in a setting which is already plagued by tribal conflict. Simultaneously, food shortages and a lack of capacity to manage displacement, recovery and disaster mitigation efforts will amplify the impacts of disasters on those who are more vulnerable, for example the poor, disabled, elderly, women, and children.

The below table summarises the status of commonly-used socioeconomic indicators through which the vulnerability of PNG can be framed.

Table 6: Summary of socio-economic data, World Bank open data complemented by country-specific data based on availability

Indicator	Score
Human Development Index	0.555
% of population below national poverty line	39.9
GINI index	41.9
Gender Inequality Index (GII)	0.725
Global Gender Gap index	0.64
Household size	6.63
Unemployment rate	2.74%
Unemployment in female labour force	1.76
Under five child mortality	43.9 per 1,000
Under five prevalence of stunting	46.5%
Proportion of seats held by women in national parliament	0%
Girls married under age of 18	27.3%

[61] https://www.papuanewguinea.travel/annual-visitor-arrivals
[62] https://www.papuanewguinea.travel/papua-new-guinea-tsdp
[63] World bank data, World Tourism Organization, Yearbook of Tourism Statistics, Compendium of Tourism Statistics, and data files. Available at: https://data.worldbank.org/indicator/ST.INT.XPND.MP.ZS?end=2018&locations=PG&start=2003&view=chart
[64] Zhou, Y., Li, N., Wu, W., Wu, J. and Shi, P., 2014. Local spatial and temporal factors influencing population and societal vulnerability to natural disasters. Risk analysis, 34(4), pp.614-639.

Land ownership in PNG is based on customary title laws, and is owned communally by specific lineage, clan or tribal group. Almost all (97%) of landowners in PNG are indigenous, and land rights are allowed to be sold or leased to landowning groups, individuals or the landless, but the PNG Constitution prohibits the sale of customary land to foreigners. Land forms the basis of production and consumption for the majority of Papua New Guineans.[65] There is significant pressure from both the Australian government and the World Bank to reform land ownership under the premise that customary land title is an impediment to development. Disputes of land and resource rights between indigenous groups, the government and corporate entities is not uncommon in PNG. Between 1989 and 1999 more than 5,000 people lost their lives on the island of Bougainville (east coast of PNG) following a fight between Bougainville Copper Limited (BCL), an Australian-owned mining company, and indigenous landowners.[66] In some cases, the association of land with community cultural cohesion and social norms in customary land systems can create obstacles for development and the implementation of adaptation measures. On the other hand, customary systems can be utilised by embedding traditional chiefs and landowners at the centre of the decision-making process helping to protect community resilience.[67]

There are no official statistics for the number of people with disabilities in PNG but the WHO estimates that 15% of the world's population have some form of disability. Generally, a person with a disability is unheard, and structures that exist in PNG society limit their opportunities and participation in society. Byford and Veenstra found that persons with disability and their family attributed disability to sorcery or other supernatural causes in PNG. Papua New Guineans tend to interpret misfortune as a failure of the person to adhere to important social rules. However, there is very little research on understanding the socio-cultural context of disability in PNG. Thus, programmes that address disability that do not account for PNG's social context tend to be ineffective.[68]

Degradation of food security

The Madang province, similar to other provinces in PNG, is heavily reliant on its agriculture sector with 80% of the population growing the food they eat while also growing cash crops. In the past, over 90% of coastal and near-shore resources were under customary ownership, with traditional knowledge applied to the day-to-day management of marine resources. Marine resources have become increasingly stressed because of pollution, overfishing, destructive fishing methods, and use of outboard engine powered crafts to access distant or protected fishing grounds. The increasing pressure on fisheries will threaten the coastal and marine habitats, the associated resources and the traditional way of life for the communities in PNG.[69] At the same time, climate change is impacting the agricultural sector due to sea level rise, increasing temperatures and changing rainfall patterns.

[65] Colman, 2018. "Customary land title and Indigenous rights in Papua New Guinea, Pacific Dynamics. Available at: https://www.researchgate.net/publication/327337319_Customary_land_title_and_Indigenous_rights_in_Papua_New_Guinea_Pacific_Dynamics_Journal_of_Interdisciplinary_Research_Volume_2_Number_1_June_2018_httppacificdynamicsnz

[66] Refworld, 2010. Papua New Guinea: Indigenous people lose of on land rights. Available at: https://www.refworld.org/docid/4c0cb60bc.html

[67] Gharbaoui, D. and Blocher, J., 2018. Limits to adapting to climate change through relocations in Papua-New Guinea and Fiji. In Limits to climate change adaptation (pp. 359-379). Springer, Cham.

[68] Byford and Veenstra, 2009. The importance of cultural factors in the planning of rehabilitation services in a remote area of Papua New Guinea. Available at: https://www.tandfonline.com/doi/pdf/10.1080/09638280320001591 67?casa_token=9nJAKeYfnYYAAAAA:YBKkf-dK-pDsUvqb9x8RGll1bDLI7qT_yQ_dG_xJcElaag1PHwFh2mENShbfLil-Cc8qYtQBVT0XTYw

[69] SPREP, 2010-2013. PNG Marine Program on Coral Reefs, Fisheries and Food Security 2010-2013. Available at: https://www.sprep.org/attachments/VirLib/PNG/marine-prog-coral-reef-fisheries-food-security.pdf

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There is growing food insecurity in PNG. Around 85% of the PNG population that live in rural communities are predominately reliant on subsistence agriculture for food and cash crop.[70] Papua New Guinea's own Second National Communication on Climate Change suggests that 63% of calories consumed in rural areas is from sweet potatoes, a crop that is projected to reduce by 10% by 2050 due to climate impacts. Other key crops are projected to decline include maize, cassava, rice, sugarcane and taro. Climate change is set to contribute to several factors of vulnerability throughout the food system (e.g., changes in the hydrological cycle due to droughts and floods resulting in crop damage, plant disease and increasing instances of pests that lead to crop failure).[71]

Gender-Specific Impacts

Gender inequality is a significant challenge in PNG: PNG is ranked 160 out of 161 countries on the United Nations Development Programme's 2021 Gender inequality index.[72] Women generally suffer from excessive workloads, malnutrition, poor access to safe water and healthcare services, unwanted pregnancies, and gender-based violence. Key barriers faced by women include but are not limited to low political representation (none of the 111 current parliamentarians are women), exclusions from decision making, discriminatory cultural practices such as bride pricing and forced marriages, engagement in economic activities that lack regulatory protection on pay and working conditions, and lack of control over land, wealth, finances and other strategic resources.[73]

Many of the challenges women face are likely to become more pronounced with increasing climate risk.

Gender-Based Violence

Gender-Based Violence (GBV) is incredibly prevalent in PNG and has been recognized by the Department for Community Development (DFCD) as a serious problem. For example, 41% of men in PNG admit to having raped someone, and over two-thirds of women are estimated to have suffered a form of sexual violence in their lifetime.[74] Around the world, climate and geophysical disasters have been shown to worsen GBV. One of the reasons for this is the social and psychological pressure that arises from loss of livelihood and income. Another reason is due to displacement. A report by CARE highlights that one in five women who are displaced experience sexual violence.[75]

[70] https://www.aciar.gov.au/publication/aop2021/papua-new-guinea#:~:text=Papua%20New%20Guinea%20is%20the,for%20food%20and%20cash%20income.

[71] Rosenzweig et al., 2001. Climate Change and Extreme Weather Events; Implications for Food Production, Plant Disease, and Pests. Available at: https://link.springer.com/article/10.1023/A:1015086831467

[72] UN Women, 2020. Gender Alert on Covid-19 in Papua New Guinea. Available at: https://asiapacific.unwomen.org/sites/default/files/Field%20Office%20ESEAsia/Docs/Publications/2020/08/Gender%20alert%20on%20COVID19%20IN%20PNG%20l%20Issue%201.pdf

[73] Japan International Cooperation Agency, 2010. Country Gender Profile Papua New Guinea. Available at: https://www.jica.go.jp/english/our_work/thematic_issues/gender/background/pdf/e10png.pdf

[74] ODI, 2015. Gender violence in Papua New Guinea. Available at: https://cdn.odi.org/media/documents/9886.pdf

[75] CARE, 2020. Gender-Based Violence GBV) and COVID-19 the Complexities of Responding to "The Shadow Pandemic". Available at: https://www.care.org/wp-content/uploads/2020/07/care_gbv_and_covid-_policy_brief-final.pdf

After the 2005 eruption of Manam volcano, women refugees reported that in the "temporary camps" they endured inadequately built latrines with little privacy, very few female health workers, and GBV in and out of the camps. Although there are many reasons why GBV occurs, in PNG it is perpetuated by cultural norms that marginalise women and strict gender roles that condone, tolerate and enforce gendered violence.[76]

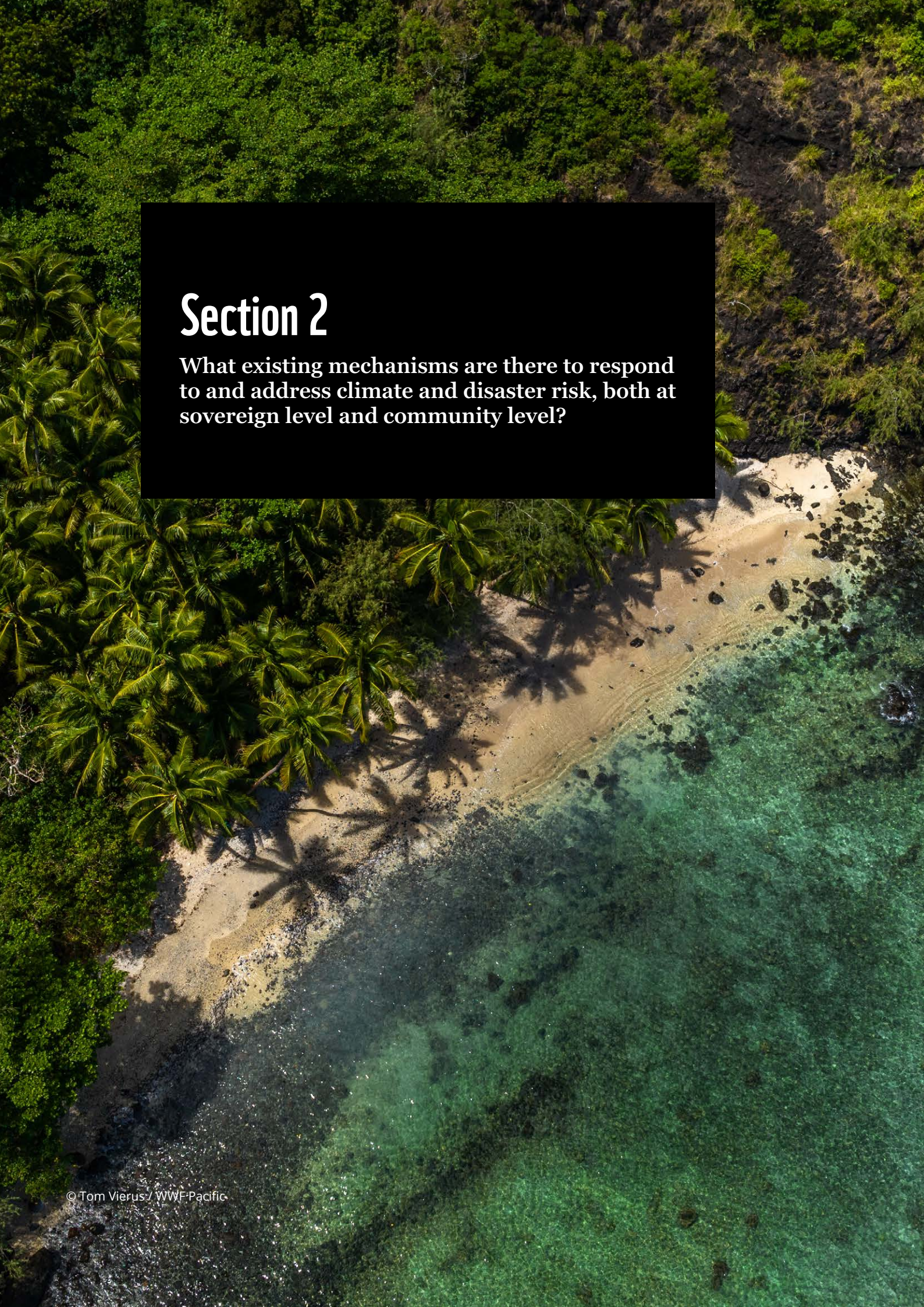
Women and Fisheries

In coastal areas the general norm is for men to go deep-sea fishing in boats, while women move along the coastline usually catching small fish, crabs and various shellfish for household consumption. Typically, this activity is unofficial and rarely appears in official statistics, but it is estimated that women's involvement in the fishing industry accounts for 20% of the annual yields.[77] The business customs for small business are mostly unfavourable to women, with low profit margins. Women market sellers will usually sleep at the market to avoid accommodation costs. This poses a significant risk of sexual abuse or assault when sleeping, and many women experience sexual harassment and abuse at the market.[78] Economic planners overlook women in the fisheries industries, meaning donor and government schemes focus efforts on commercial offshore fishing, of which the beneficiaries are mainly men. Women are underrepresented in the national fisheries agency, fishing training courses and fishery-related meetings. Exclusion of women from development and decision-making processes seriously hinders the effect of various development efforts within the country. Therefore, because women's voices are not being heard they will be disproportionately affected by a decrease in the abundance of fish due to damaged coral reefs and other factors.

[76] https://femilipng.org/wp-content/uploads/National-Strategy-to-Prevent-and-Respond-to-GBV.pdf
[77] Japan International Cooperation Agency, 'Country Gender Profile: Papua New Guinea'. Available at: https://www.jica.go.jp/english/our_work/thematic_issues/gender/background/pdf/e10png.pdf
[78] Ibid.

Section 2

What existing mechanisms are there to respond to and address climate and disaster risk, both at sovereign level and community level?



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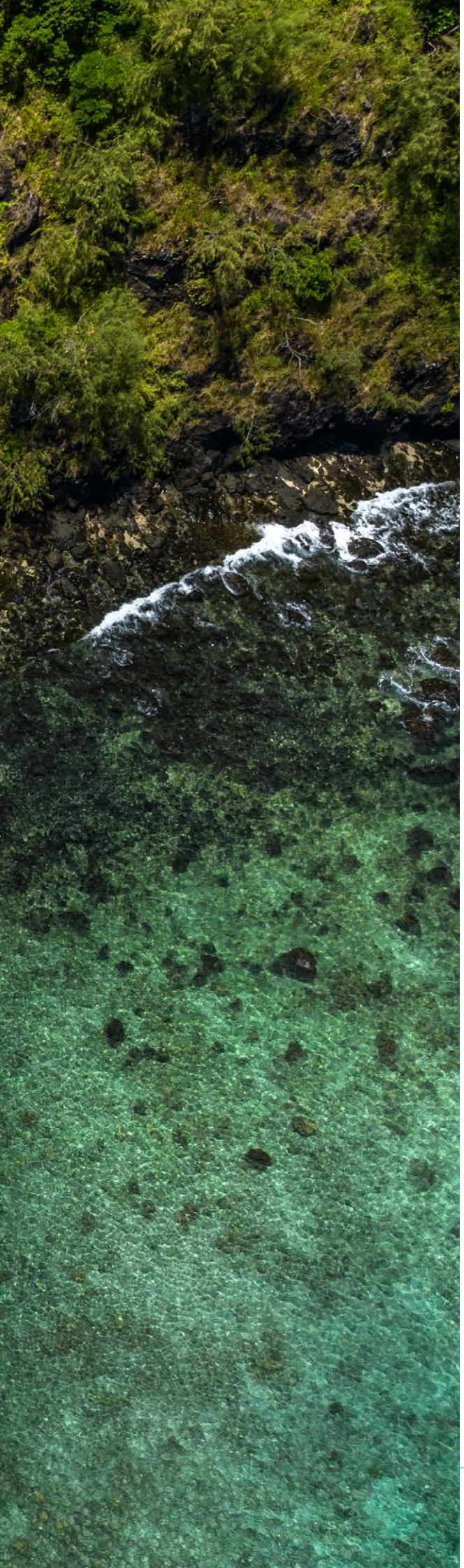
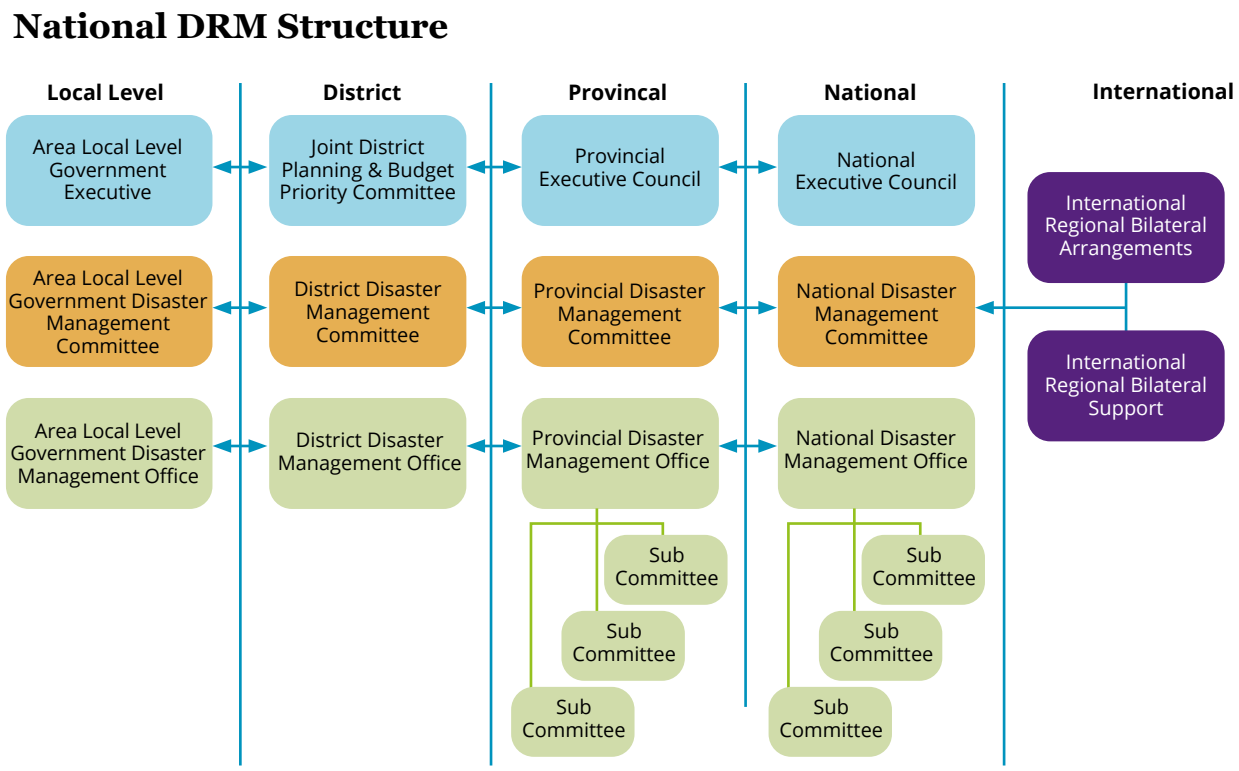


Existing Government-Level Response and Financing Mechanisms

PNG's Disaster Management Framework is set out in the Disaster Management Act (DM Act) 1984 (revised in 1987). The Act is widely accepted as requiring updating and is currently under review. Consultations have identified important gaps such as the absence of dedicated funding or easy access to funding during emergencies and the lack of clear coordination mechanisms under the current legal framework or addressing of the coordination of international aid. Under the Act, the National Disaster Committee and its executive National Disaster Centre (NDC) are the lead government agency for disaster response at a national level. However, in past disasters, the Emergency Controller has been appointed by the Government of Papua New Guinea (GoPNG) to lead disaster response efforts in coordination with the NDC, which has a limited budget and capacity to operate. At the provincial level, each province has either a disaster coordinator or an established Provincial Disaster Centre (PDC) who is in charge of the disaster response. For example, the Madang province has an active PDC, which responds to earthquakes, tsunamis, volcanic eruption, and flood hazards. Most of the PDCs are, however, heavily indebted, suffering also from a lack of resources. At the district and local-level government (LLG) levels, if there is a Disaster Risk Management (DRM) and disaster response mechanism, it likely leaves all responsibility to a single person who is also charged with other administrative responsibilities. The NDC has limited coordination with or authority over sub-national (province, district, LLG) disaster management committee or disaster offices, with vertical coordination challenged by geographical dispersion and a lack of coordination mechanisms.[79]

[79] Papua New Guinea - Disaster Management Reference Handbook June 2022. Available at: https://reliefweb.int/report/papua-new-guinea/disaster-management-reference-handbook-papua-new-guin

Figure 12: PNG's national disaster management structure. Sourced from Disaster Management Reference Handbook – Papua New Guinea (June 2022).



The National Disaster Mitigation Policy was issued in 2010 and recommended the creation of a National Environment and Disaster Mitigation Authority. The suggested Authority would merge the current NDC and undertake disaster management responsibilities, as well as environment and disaster mitigation initiatives throughout Papua New Guinea. The Authority's primary roles would include implementing the National Environment and Disaster Mitigation Program, creating and managing mitigation programs and policies, and raising and managing financial resources. However, there is no information on whether the policy has been put into practice.[80]

Post-Disaster Funding

Currently, the PNG government mainly relies on ex post instruments such as budget reallocation, donor assistance and external debt to manage the fiscal impacts of disasters. Since 2015, ex ante mechanisms available to the PNG government include budget appropriation for the NDC of USD 2.8 million under the Department of Provincial and Local Government (DPLGA), named the Special Support Service budget. The PNG National Budget also includes USD 10.7 million that can be allocated within the Treasury and Finance miscellaneous budget for unforeseen needs.[81]

In the aftermath of disasters such as the Manam Volcano Eruption, King Tides, and the Polio Outbreak, Papua New Guinea (PNG) received funding from various sources to support relief and recovery efforts. The PNG Treasury's Final Budget Outcome for 2019 reports that in that year, the country received K1.7756 billion in donor aid, with K1.4085 billion from foreign governments and K367.1 million from international organizations[82].

Relief efforts for the Manam Volcano Eruption were supported by the government and international bodies such as the European Commission, Asian Development Bank (ADB), and USAID. The government released USD 88,000 in relief funds[83], while

[80] Relief Web, 'Disaster Management Reference Handbook – Papua New Guinea' (2020) Available at: https://reliefweb.int/report/papua-new-guinea/disaster-management-reference-handbook-papua-new-guinea-june-2022
[81] https://www.financialprotectionforum.org/sites/default/files/PNG_4-pager_Profile_DFRIP_Mar18_WEB.pdf
[82] https://www.businessadvantagepng.com/development-aid-in-papua-new-guinea/
[83] https://reliefweb.int/report/papua-new-guinea/png-govt-releases-relief-funds-manam-islanders

the European Union provided EUR 200,000.[84] Following on from this disaster, the ADB and AusAID-supported Microfinance and Employment Project established 52 community development centers across the province of Madang, benefiting over 5,000 members[85].

Following the king tides in January 2021, USAID partnered with IOM, UN OCHA, and Australian DFAT to provide assistance to affected communities. Shelter tool kits were distributed to ensure that at least 900 vulnerable individuals in Manus, East Sepik, and AROB had the necessary tools to rebuild their homes. Additionally, up to 2,000 households received collapsible water containers and water treatment tablets to improve access to drinking water[86].

In addition, the government and international organizations, such as UNICEF, WHO, and Gavi, the Vaccine Alliance, launched a large-scale vaccination campaign to contain the 2018 polio outbreak in PNG. The World Bank provided a $15 million grant to support the government's efforts to strengthen the country's health system and improve its capacity to respond to health emergencies[87].

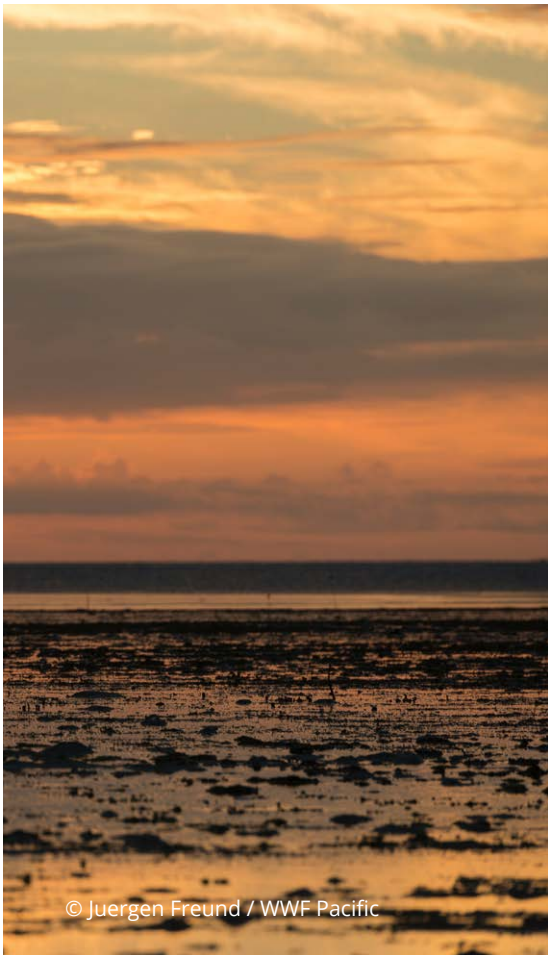
The government tries to provide some form of relief measures following a disaster, but with limited public records of financial inclusion, this does not transfer to the household level. For example, during COVID-19 relief was provided through district grant mechanism, but this was poorly targeted. The above examples of disaster response illustrate the dependence of the PNG government on external aid following an event. Therefore, the ability of the government to provide assistance to the fishing communities targeted by this project is limited by ex-post fundraising constraints.

Gender mainstreaming in Disaster Risk Management (DRM)

The NDC is the PNG government department for disaster management which coordinates provincial disaster management. NDC's National Disaster Risk Reduction Framework of Action 2015-2017 recognised the importance of women's participation in DRM; however, a gender lens has not been effectively incorporated into DRM.[88]In NDC's National Disaster Risk Reduction Framework of 2017-2030, women and their effective participation again was highlighted. The 2017-2030 reports also recognised the critical need to empower vulnerable groups (women, persons living with disability, elderly, children etc.) to participate and equally benefit in the response, recovery, rehabilitation and reconstruction phase.[89] Although the first step is to recognise the different impacts faced by vulnerable groups, it is not clear whether there is an integral element of planning and implementation to actively engage vulnerable groups in DRM.

PCRIC

Currently, PNG has opted out of an insurance policy from the Pacific Catastrophe Risk Insurance Company (PCRIC). PCRIC, a regionally dedicated insurance company, is owned for the benefit of Pacific Island Countries and Territories (PICTs), through the Pacific Catastrophe Risk Insurance Foundation (PCRIF). PCRIC's key objective is to provide disaster risk finance products, including catastrophe risk insurance for natural and climatic disasters which impact PICTs, with an aim of providing liquidity to enable governments to deliver emergency response requirements as soon as possible after a disaster. Currently, PCRIC offers tropical cyclone and earthquake products and are in the process of developing drought and excess rainfall products. It is in discussions with PNG over providing earthquake cover. If a triggering event were to happen, such funds could be used in the fishery sector if the model generates a pay-out and the government identify the fishing sector as a key priority area (i.e., the ultimate expenditure decision is at the discretion of the government of PNG).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[84] https://ec.europa.eu/echo/files/funding/decisions/2005/dec_papua_01000.pdf
[85] https://www.adb.org/results/rebuilding-after-disaster-microfinance-rescue-papua-new-guinea
[86] https://pg.usembassy.gov/usaid-partners-with-iom-un-ocha-and-australian-dfat-to-deliver-assistance-to-communities-affected-by-king-tide-flooding-in-papua-new-guinea/
[87] https://borgenproject.org/dual-outbreaks/
[88] Papua New Guinea: National Disaster Risk Reduction Framework 2017-2030.
[89] Papua New Guinea: National Disaster Risk Reduction Framework 2017-2030.

Existing Community-Level Response and Financing Mechanisms

The government provides no nationwide social protection system, and only basic health services and partially subsidised education. Workers in the formal sectors remit a portion of their income to families and communities in their home provinces, predominantly rural areas. The government and most provincial authorities recognise that NGOs and CSOs provide critical complementary service delivery systems both on a routine basis and in times of disaster.[90] For many people in PNG, their main source of social protection is informal, derived from shared land ownership and extended family and Wantok groups.[91]

Insurance penetration is low at under 2%, which means the majority of the population is uninsured when a climate event happens. Whilst levels of financial exclusion in PNG are unknown, it is estimated 85% of the population does not have a bank account. In rural areas, indications of financial exclusion may be as high as 98%. PNG has made micro-insurance a priority in order to help to get more people insured; however, progress is challenging as local populations have not been exposed to institutions providing private, commercial cover, and there is a lack of basic understanding of what insurance is and how it works.

Community Level Response

Before the development of technologically advanced early warning systems or the establishment of response operating procedures, PNG communities, particularly along the coast, developed ways to forecast hazards, reduce disaster risk and respond to emergencies. Knowledge and indigenous beliefs have been passed down from generation to generation and helped build resilience in the face of climate and disaster risk. Leveraging this existing indigenous knowledge in disaster risk reduction is key to the long-term success of disaster risk reduction. Indigenous knowledge is being rapidly lost due in part to today's "modern" strategies, leaving exposed communities and specific vulnerable groups with fewer capacities to respond to extreme weather and loss of habitable and arable land.

Local knowledge in the form of traditional building structure design has been seen to be very effective to address flooding. In particular, communities on grassland and flood plains traditionally construct their houses on stilts, with the ability to be raised or lowered depending on that year's level of inundation. It has been seen that during times of extreme floods the stilts are raised by nearly 3 times the normal height.[92] Communities in the Oro province construct their houses out of material that are strong and lightweight that can resist wind but causes limited damage in case of collapse. After the eruption of Manam volcano in 2004 the population was resettled in the coast of Madang. Where traditional material like wood frames, bamboo walls, black palm (limbum) floors and coconut frond roofs were used this was a source of conflict when resources are limited, exacerbated further by loss of land due to flood inundation. To generate income for basic repairs like fixing ladders and replacing roofs made of coconut fronds, the resettled community would engage in selling fish. This encourages greater dependence of indigenous populations on the cash economy, hence being relatively poorer than when they were more self-sufficient.[93] The need to generate income by fishing can also exacerbate pressure on fish stocks, generally, and especially in the aftermath of an event.

Communities in PNG have strong traditional bonds even in times of crisis. During a disaster, people are reliant on natural inter-community supply chains. During period of flooding, communities adapt by use of canoes to move between villages and provide material and emotional support. Traditionally, PNG has voluntary collective action called *wantok*; in normal times, villages will assist each other by helping build or move a hut or plant crops. During a disaster, the *wantok* system is leveraged to support relief and recovery needs. Similarly, it is the community involvement that is a key element to all early warning systems. For example, if a community member observes signs of heavy rain that could be a sign of an impending flood, the community responds by packing belongings and ensuring food supply is plentiful. A "spotter" is sent upstream to survey the change in river water level, they then report back to the community and the warning is passed from person to person. Additionally, they may also rely on the

[90] https://bti-project.org/en/reports/country-report/PNG

[91] International Labour Office, 'Review of the Social Security System: An initial assessment' (2006). Available at: https://www.social-protection.org/gimi/gess/RessourcePDF.action;jsessionid=UMZCi5qFmzHgDGjxiafwD8tt7O7oxKQMiDAmcjCKrhtI6rAYZ28K!539423187?id=5500

[92] ReliefWeb, 2010. Papua new guinea: Residents coping with rising flood waters – for now. Available at: https://reliefweb.int/report/papua-new-guinea/papua-new-guinea-residents-coping-rising-flood-waters-now

[93] IOM, 2016. Another manam? The forced migration of the population of manam island, Papua new Guinea due to volcanic eruptions 2004-2005. Available at: https://publications.iom.int/books/another-manam-forced-migration-population-manam-island-papua-new-guinea-due-volcanic

use of garamut drums, lighting fires, shouting and producing loud noises. Warning is heeded by community members because there are high levels of risk awareness from story-telling of past events by community elders.[42]

Shaw and Baumwoll found that land use planning has often been influenced by hazard vulnerability. Communities would locate their settlements on high ground to avoid storm surges and floods. One community was found to create a hand-dug drainage system surrounding their houses to direct flood water away from critical areas. In case of an extreme flood, communities would allocate an emergency area to which they would evacuate. However, it is uncertain whether these community-led and customary protection mechanisms remain viable today with an increased risk due to climate change.[94]

Madang Province is PNG's third leading producer of cocoa and copra and second of cattle. Farmers experience issues ranging from global market competition for cash crops such as coffee, shortages in labour, to diseases. In light of these issues, traditional subsistence practices are changing to adopt other farming methods such as agroforestry. Agroforestry combines agriculture with forestry on the same land. This promotes diversification of livelihood sources and reduces the risk of crop failure in the event of a disaster. Additionally, trees stabilise environmental temperatures, help to conserve soil water, contribute organic fertilizers to the soil and can be a source of construction material for new buildings.[95]

Women-led responses

Women in PNG have been building resilience in communities by creating the Mangoro Market Meri (Mangrove Market Women) to manage sustainable harvest of mangroves.[96] Climate change directly threatens the mangrove ecosystem through processes such as sea level rise, increased temperature, changes in precipitation, increased storminess and increased CO_2.[97] Communities in PNG are highly reliant on mangroves: they are the breeding grounds of fish and shellfish and buffer coastal communities against the impacts of king tides and storm surges. The long-term preservation of mangroves has been assisted by women who have addressed the issues of over-fishing and over-harvesting, and implemented mangrove replantation strategies. This serves as a compelling demonstration of how women's active participation in environmental conservation and decision-making can lead to a more thriving and sustainable future.[98]

Gender relationships have to be considered carefully in PNG. Men are the head of the household and are the dominant role in decision-making. Women have adapted by forming their own separate associations in a traditionally male dominated society. In the absence of formal credit institutions, women create their own clubs; women form clubs where members can seek mutual insurance by contributing savings for protection against unforeseen shocks. In PNG, these groups are known as the *"Sandes"* and the Mother's Groups known as *"Wok Meri"* are common in low-income groups. The Wok Meri groups work to empower by using a mentoring system, whereby each new member is paired with a more experienced *Wok Meri* group/member with which knowledge and support is shared.[99] Women members can obtain a small loan from many other members of the group. This type of organisation is built on trust among members and a shared risk mechanism that acts as "collateral". Women's community-based organizations (CBOs) have the potential to reduce vulnerability within livelihood systems by providing support and resources to help people diversify their income streams, build resilience to shocks and stresses, and develop sustainable practices for resource management. This can lead to greater economic security, improved access to essential services, and better overall well-being for individuals and communities facing climate-related disasters.[100]

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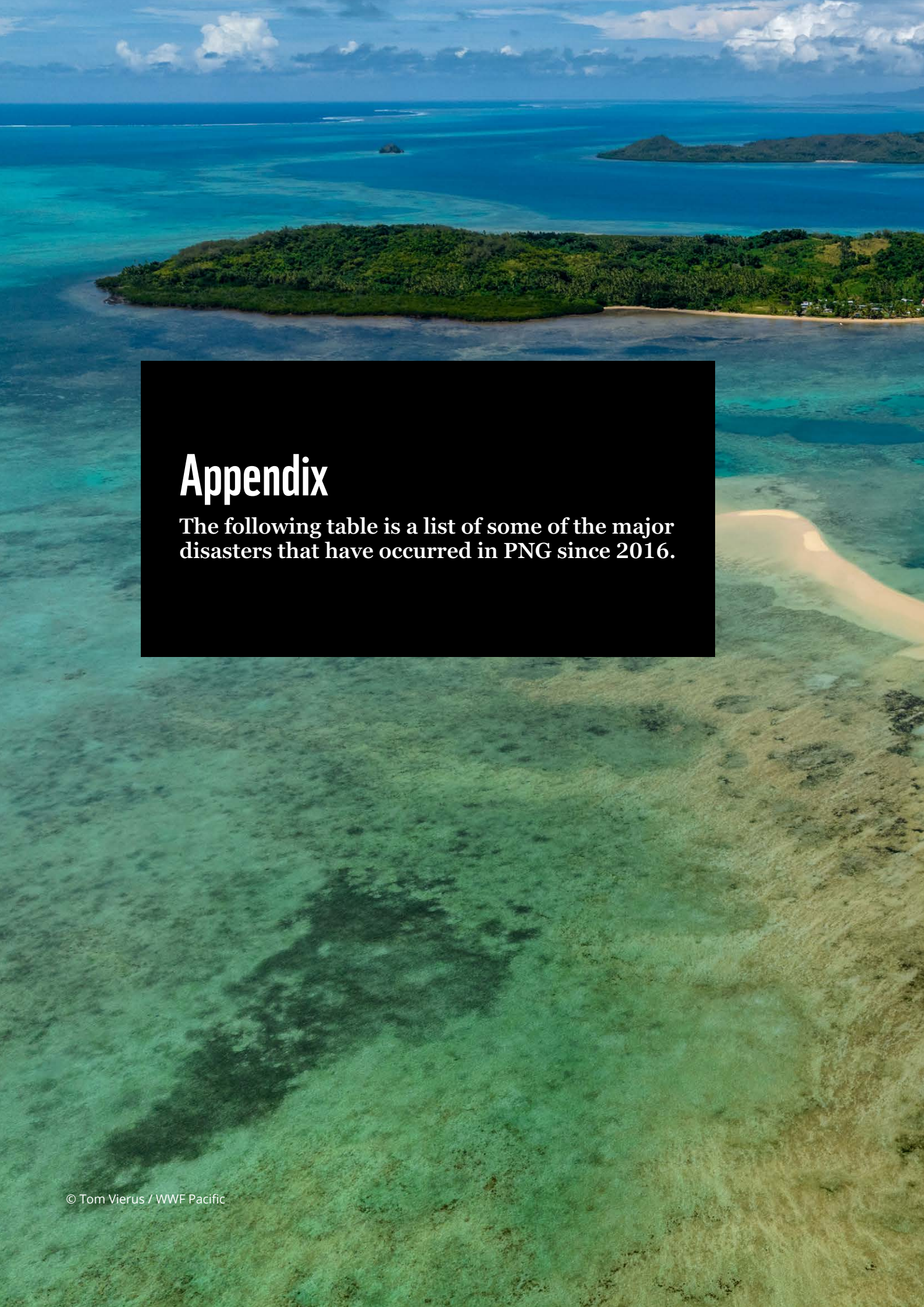

Appendix

The following table is a list of some of the major disasters that have occurred in PNG since 2016.

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Table 7: Major disasters that have occurred in PNG since 2016. Data was sourced from 2022 Papua New Guinea: Disaster Management Reference Handbook[101].

Disaster	Date	Disaster Description	Impacts
Manam Volcanic Eruption	April 2022	The ash plumes reached an estimated height of 13.7 km	No casualties, but three communities of were covered by smoke, ash, and volcanic products, affecting a number of houses, food gardens, coconut palms, wells, and water catchment facilities.
King Tides	December 2021	High tide was travelling 3-5 metres inland inundating water sources and destroying homes and food gardens.	A surge in king tides that flooded communities and displaced approximately 53,000 people.
Landslide	March 2021	Heavy rainfall occurred in Tambul-Nebilyer district (Western Highlands Province)	10 people died, and two people were missing. At least 1,000 people were affected as houses and crops were destroyed.
Ulawun Volcanic Eruption	June 2019	Began emitting ash plumes up to 20,000 m	About 12,000 people in West New Britain and 4,000 people in East New Britain provinces. About 6,800 people were evacuated.
Manam Volcanic Eruption	October 2018	7-magnitude earthquake struck the island of New Britain. followed by two aftershocks above magnitude 5	No reports of damage
Polio Outbreak	June 2018	First polio outbreak in 18 years in Morobe province.	26 confirmed cases
Earthquake	February 2018	A 7.5-magnitude earthquake struck the Southern Highlands of PNG; it was followed by hundreds of aftershocks including a 6.7-magnitude earthquake	Affected over 544,000 people in Hela, Southern and Western Highlands, and Enga provinces. An estimated 54,000 homes were damaged and 18,200 people were forced to seek shelter
Volcanic Eruption	January 2018	Volcanic activity on the southeast side of the island covered 50-60% of the island in lava	The entire population (591 people and 154 families of Kandovar Island, comprised of five community groups were evacuated.
Landslide	November 2016	A massive landslide completely covered two villages in the Southern Highlands of PNG while people slept	It killed at least 40 people.

[101] CFE-DM, 2022. 2022 Papua New Guinea: Disaster Management Reference Handbook. Available at: https://www.cfe-dmha.org/LinkClick.aspx?fileticket=AvmtAYhfkKw%3D&portalid=0

Table 8: Historical displacement events in PNG 2008-2019. Sources from internal displacement monitoring centre. Available at: https://www.Internal-displacement.Org/countries/papua-new-guinea#displacement-data

Year	Event Name	Internal Displacement	Hazard Type
2014	Gulf province flood	11000	Flood
2014	Cyclone ita	7600	Storm
2014	Angabanga river overflowing	300	Flood
2013	Enga landslide	20	Wet mass movement
2013	Western highlands flood	26	Flood
2016	Jiwaka province floods	100	Flood
2016	October floods	510	Flood
2016	February floods	1000	Flood
2008		75000	Flood
2014	Bougainville earthquake	260	Earthquake
2017	eastern highlands floods	500	Flood
2018	earthquake - southern highlands	58000	Earthquake
2019	landslide - wapenamanda (enga)	1500	Wet mass movement
2019	flooding - central province	120	Flood
2019	earthquake - morobe	640	Earthquake
2019	earthquake - duke of york islands	300	Earthquake
2019	flood - western highlands	5000	Flood
2019	vanuatu tropical cyclone oma	300	Storm
2019	floods - daulo district (eastern highlands)	20	Flood
2019	Australia; cyclone trevor	420	Storm
2019	floods - chimbu	20	Flood
2019	floods - raicoast district (madang)	74	Wet mass movement
2019	flood - east new britain	270	Flood
2020	flood - goroka (nupaha)	2500	Flood
2020	flooding - chimbu province	700	Flood
2020	land erosion - lae (busu compound)	98	Wet mass movement
2020	landslide - western highlands (tambul)	52	Wet mass movement
2020	landslide - huon-gulf (morobe)	200	Wet mass movement
2020	landslide - chimbu (gembogl)	5	Wet mass movement
2020	king tide - bougainville (deos-tinputz)	180	Wet mass movement
2020	flash flooding - eastern highlands	200	Flood
2021	floods - southern highland province (ialibu pangia district, tiri village)	50	Flood
2021	king tide - bougainville, new ireland island, manus and east sepik provinces	7200	Wet mass movement
2021	landslide - southern highland province (topa, mendi)	70	Wet mass movement
2021	landslide - western highlands province (mul baiyer lumusa district, lumusa)	30	Wet mass movement
2021	- landslides - western highlands province	100	Wet mass movement

Year	Event Name	Internal Displacement	Hazard Type
2021	landslide - western highland province (mount hagen district, mount hagen)	5	Wet mass movement
2014	Mt. tavurvur eruption	220	Volcanic activity
2014	Mt bagana eruption	1400	Volcanic activity
2017	manam volcanic activity	890	Volcanic activity
2018	volcanic eruption (manam) - manam island	2000	Volcanic activity
2018	volcanic activity - kadovar island - 5/1/2018	740	Volcanic activity
2019	volcanic eruptions (mount ulawun) - new britain	2800	Volcanic activity
2019	volcanic eruptions (mount ulawun) - new britain	16000	Volcanic activity
2019	volcanic eruptions (mount manam) - manam	3800	Volcanic activity

Table 9: List of historical events from CFE-DM, 2022 Papua New Guinea: Disaster Management Reference Handbook.

Hazard	Name	Date	Description
Volcanic	Manam Island Eruption	2022	Over 1.4 million people were affected and an estimated 500 dead.
Volcanic	Manam Island Eruption	2018	Ash cloud blocked the sunlight on the island
Volcanic	Manam Island Eruption	2015	Produced a ash plume over 35 km N and NW at an altitude of 3 km
Volcanic	Manam Island Eruption	2010	Volcano released a thin, faint plume on June 16, 2010, as clouds clustered at the volcano's summit.
Volcanic	Manam Island mudslide	2007	Three people were killed by mudslide on the northern part of Manam island.
Volcano	Manam Island	2006	Eruption column to 19 k altitude and forced evacuation of inhabitants
Volcano	Manam Island Eruption	2005	Eruption injured 14 and killed 1 at Warisi village
Volcanic	Manam Island Eruption	2004	Major eruption forced the emergency evacuation of over 9,000 inhabitants. 5 people were killed.
Seismic	M7.6 Markham Valley Earthquake	2022	Damaged the Ramu hydropower plant, resulting in total system outages across Madang. Undersea cable linking Madang to Port Moresby was affected by the quake.
Seismic	M6.3 earthquake	2017	Earthquake close to the highlands
Seismic	M6.2 earthquake	2012	Near the North Coast of PNG.
Seismic	M6.2 earthquake	2012	Southeast of Angoram town,
Seismic	M6.8 earthquake	2012	Bismack Sea, 150 km East of Madang
Seismic	M6.5 earthquake	2010	Magnitude 6.5 earthquake, 36 km southwest of Long Island
Seismic	M6.8 earthquake	2006	Magnitude 6.0 earthquake, 54 km west of Long Island
Seismic	M6.2 earthquake	2005	Magnitude 6.2 earthquake, 56 km wester of Madang
Landslide	M7.6 earthquake triggered landslide	2022	Earthquake 67 km east of Kainantu, landslides were reported in Madang
Landslide	Finisterer	2019	Two buried under landslide triggered by heavy rain.
Landslide	Madang highway Landslide	2010	More than 150 vehicles and hundreds of people were stranded at Usino Junction due to landslide blocking Madang-Ramu Highway.
Tsunami	Aitape Tsunami	1998	An underwater landslide caused a tsunami that killed 2,200 people, injured thousands, left 9,500 homeless.
Flood	Floods	2009	Flooding and landslides in the Sialum District in Morobe Province killed 19 people
Flood		1998	Flooding in the Middle Ramu District killed 18 people.

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