Pacific Island Countries: An Early Warning of Climate Change Impacts

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Pacific Island Countries: An Early Warning of Climate Change Impacts

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Introduction to Planetary Health

Planetary health is a multi-disciplinary approach that addresses the interconnections between the processes of environmental change and their impacts on human health and well-being, at scale. The planetary health concept builds on the ecological framing of planetary boundaries and supports the UN Sustainable Development Goals and the Paris Climate Change Agreement, both of which recognize the importance of regional and global coordination to solve complex environmental and development challenges.

Links between environmental change and human health are both direct (e.g. impact of air pollution on respiratory and cardiac functioning) and indirect (e.g. extreme weather events or sea-level rise leading to permanent displacement) but there is plausible connection between the change in natural systems and human well-being. The planetary health approach requires transboundary perspectives covering issues that one country cannot address in isolation. Solutions, however, may be local, national, regional or international.

The work of The Rockefeller Foundation Economic Council on Planetary Health, through its Secretariat based at the Oxford Martin School at the University of Oxford, aims to provide a policy-oriented, economic perspective to developing solutions. The central economic concept is that externalities – or costs and benefits to another party that are not priced, regulated or consented to – should better address planetary boundaries than at present. The analysis pays attention to equity and distributional issues, recognising how different people, institutions, countries and trajectories of development are affected by the impact of planetary health and the measures proposed to address it. This work seeks to target recommendations at global and national policy-makers.

A series of background papers has been developed by the Secretariat. These papers aim to illustrate where solutions might be identified and applied, diagnosing planetary health issues by highlighting drivers of change, significant environmental impacts and the resulting human health impacts.

This paper explores the impacts from climate change and associated sea level rise on human health and livelihoods. Small islands states, particularly in the Pacific, are on the front line of these impacts, and this paper identifies fisheries as key sources of government revenue and economic livelihoods in Pacific Island Countries that are at risk. The governance of the response to the challenges that Pacific Island Countries face are a key topic of this paper, including the issue of climate-related migration and refugees.

Sam Bickersteth
Executive Director, The Rockefeller Foundation Economic Council on Planetary Health

The full set of papers can be accessed at: *www.planetaryhealth.ox.ac.uk/publications*.

Executive Summary

Key Points

- The small islands that make up the Pacific Island Countries (PICs) are at the forefront of climate change impact from sea-level rise and extreme weather events. Without significant global and international action, this threatens to hinder economic growth and erase years of development work.
- Long-term climate change and short-term extreme events are already having significant impact on many aspects of regional and international governance, including sovereignty, citizenship and fishery rights, as well as on economic development and health.
- The ripple effect from fisheries in particular, including changes in the location and size of key stocks (30% of the global tuna catch is harvested in the Exclusive Economic Zones – EEZs – of PICs), may result in PICs losing a key revenue stream with global markets soon feeling the knock-on effect.
- Temporary or permanent displacement of people due to climate change poses difficult questions regarding statehood and identity. Currently, climate change does not constitute a justification for refugee status.
- Physical maritime boundaries are dynamic, not fixed; they are measured against a baseline of coastal markers at low tide. As sea levels change, nations need to take steps to protect their maritime zones, land rights, national identities and concepts of citizenship.
- Data quality, quantity and management must improve to meaningfully test the relationship between long-term anthropogenic climate change and societal outcomes, so that better ways to identify true causal mechanisms can be developed, interpreted and communicated to the international community.

Pacific Island Countries (PICs), most of which are small independent island states, are on the frontline of the threat from anthropogenic climate change. Direct impacts such as damage to property and risk to human health from extreme weather events, as well as indirect effects through long-term inundation, salination of inland water courses, reduction in economic productivity, and increasing stress upon their health and governance systems, all threaten significant impacts on economic development and human well-being.

Anthropogenic global warming threatens to inundate coastal regions, contributing to land loss and altering PIC ecosystems. Changing precipitation patterns impact the replenishment of freshwater reserves, exacerbating resource challenges already strained by population rise, agriculture and urbanisation. The degradation of natural environments by strip mining, deforestation and other destructive processes have resulted in biodiversity loss, and have altered the diets and food systems of local inhabitants. But, it is through water that environmental change exerts its most immediate impacts.

Climate change-related disasters can cause prolonged hardship in communities for years following the event. Losses can slow or halt economic activity in sectors and also impact resource flows, reallocating funds from the health or education sector to meet disaster relief needs.[3]

Early warnings

PICs have contributed the least towards climate change, yet feel its effects on their land and livelihoods, especially in the areas of fisheries, agriculture and tourism. The geographical remoteness and limited human capital of many of these islands afford them little agency.[57] However, the large proportion of their, albeit small, populations and critical infrastructure located in low-elevation coastal zones (land adjacent to the coast within 10 metres above sea level) offer potential early warnings of future challenges likely to be faced by larger island nations, and of all nations with a high proportion of coastal land, as sea levels continue to rise.[51]

The environmental changes they are experiencing and the impact these have on the health of human populations threaten to alter the environmental limits within which humanity can flourish. This requires urgent attention from all nations.

The declining physical and mental health of affected communities threaten to put increasing pressure on public health services at a time when economic growth is likely to slow or stall, leaving scant funds for health services; health infrastructure is likely to be impacted by storms and flooding, and health professionals will be tempted overseas by better opportunities and more secure livelihoods. Key industries such as fisheries, travel and tourism will struggle to keep up with the increasing demands on the public purse, with little incentive for private sector investment. The increased migration of human populations, suggests that, in particular, the legal rights of displaced populations need to be urgently addressed. Currently, they do not count as legal refugees.

Urgency of the situation

> *"Adaptation opportunities will be reduced and the risks of unavoidable damages increased (medium confidence) in vulnerable regions, including small islands, that are projected to experience higher multiple inter-related climate risks at 1.5 °C global warming compared to today, with risks increasing further with warming of 2 °C (high confidence)."*[44] *– IPCC Summary for Policymakers, Special Report on Global Warming of 1.5 °C (SR15) Section B6.1*

The urgency of the challenge posed by climate change on Pacific Islands cannot be emphasised enough. Keeping the international spotlight on PICs and their vulnerability is critically important. At the local level, clear and relevant information must be conveyed to help those making decisions about their own or others' livelihoods act in a sustainable manner rather than short-term quick fixes.[34,61] Clear scientific communication, advocacy and cross-disciplinary research are needed to

understand the challenge fully and to highlight the early warnings provided by PICs to the rest of the world.

Importance of oceans in global governance

Internalizing human investment, building expertise from within, and developing and strengthening national governance structures are vital investments to PICs. Organisations such as the Alliance of Small Island States (AOSIS) ensure representation in international bodies, while regional support structures such as the Pacific Islands Forum Secretariat (PIFS) will collectively enable sustainable development in PICs. The success of such alliances is tangible: in 2017, Fiji became the first small island developing state to provide the president of the annual Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC).

Ensuring that the international community recognises the role of oceans in climate change will allow for a concerted global effort in addressing environmental change. The impact of climate change on the livelihood and well-being on Pacific Island populations offers a case study and an early warning of the likely impacts on the global economy and planetary well-being. Using PICs as an illustration, this paper offers insight into what may be foreshadowed for other coastal nations if climate change is not immediately addressed.

Contents

1. Background Information

1.1 Pacific Island Countries (PICs)

There are an estimated 7,500 islands spread across the 30 million square kilometres that make up the tropical region of the Pacific Ocean. Of these islands 500 are inhabited, of which 14 are independent nations (including Timor-Leste), and several others French or US territories. The largest independent nation is Papua New Guinea, with nearly half a million square kilometres of land. Four other nations each cover 12,000-30,000 km^2 and five countries cover 500-3,000 km^2. Tuvalu covers 26 km^2 and Nauru 21 km^2. Six islands are mountainous volcanic countries, and nine have low-lying coral atolls. On some islands, land rises only 3 metres above sea level.[2] Most of the low-lying coral atoll nations have exclusive economic zones (EEZs) – in which only they are allowed to fish, or must issue permits for others to fish – stretching 200 nautical miles into remote areas of the Pacific Ocean (Table 1).

Country	No. of Islands	Length of coastline, km	Total land area, km^2	Population, 2014	GDP, US$m	Island setting	Area of EEZ, km^2
Cook Islands	15	454	296	19,800	183	Reef	1,968,481
FSM	607	1,036	702	111,560	331	Reef	3,006,358
Kiribati	33	1,845	995	104,488	180	Reef	1,054,071
Marshall Islands	34	2,172	286	54,820	178	Reef	1,999,586
Nauru	1	19	23	10,800	60	Limestone	308,044
Niue	1	75	298	1,480	10	Limestone	317,061
Palau	250	514	495	20,500	272	Limestone	605,985
Samoa	7	482	3,046	182,900	995	Volcanic	131,035
Solomon Islands	413	8,848	29,672	547,540	1,046	Volcanic	1,598,119
Tonga	176	929	847	103,350	523	Limestone	665,033
Tuvalu	9	233	26	9,561	35	Reef	753,473
Vanuatu	82	3,234	13,526	245,860	687	Volcanic	638,541
American Samoa	7	116	199	54,517	575	Volcanic	405,088
Fiji	332	1,129	18,300	903,207	7,292	Volcanic	1,256,759
French Polynesia	126	2,525	3,827	280,026	7,150	Reef	4,784,119
Guam	1	125.5	544	161,001	4,600	Composite	(see Northern Mariana Is.)
Hawaii	16	1,858	16,635	1,419,561	75,200	Volcanic	2,470,985
New Caledonia	30	2,254	18,275	267,840	11,100	Limestone	1,419,960
Northern Mariana Islands	16	1,482	464	51,483	733	Volcanic	973,405 (includes Guam)
Papua New Guinea	440	5,152	452,860	6,552,730	18,110	Volcanic	2,388,742
Pitcairn	4	51	47	48	n/a	Reef	837,432
Tokelau	3	101	12	1,337	1.5	Reef	319,927
Wallis and Fortuna	14	129	142	15,561	60	Reef/Volcanic	258,585

Note: FSM represents the Federated States of Micronesia

Table 1: Characteristics of the 23 South Pacific Islands, adapted from Kumar & Taylor (2015)[51] with EEZ statistics from Costello et al. (2010)[22]

1.2 Climate Change Predictions

PICs are at the forefront of climate change impacts. Across the Pacific, climate change is spatially variable (Figure 1) and is driven strongly by the interaction of the ocean and atmosphere through El Niño/La Niña events. Climate model projections of three key metrics for strong and zero emissions scenarios reveal that mean temperature will rise by ~2.5 °C and ~0.5 °C, respectively, by 2100 (with uncertainty of around 0.25 °C). Under the same scenarios, mean daily precipitation will increase by ~2500% and ~600% by 2100, while sea level will rise by ~90 cm and ~45 cm by 2100, respectively.

While sea-level rise is a long-term cause for concern, its immediate scope of influence is to change the frequency and magnitude of extreme sea-level events like high tides, wind-driven waves and storm surges created by tropical cyclones and storms. Hydrological extreme events are expected to increase in severity with climate change.[3] At present, around 69% of external shocks (economic and environmental extremes) in the Pacific are attributable to hydrological events such as storm surges, cyclones, flooding and landslides.[50,60,92] These events can hinder economic growth and erase years of development work in and around the states they impact.

The debate about climate change is immutable to PIC nations as they are already experiencing its effects. The clearest example of this is sea-level rise that threatens the continued existence of their low-lying island communities. Additional threats to their security include freshwater reserves, diet and food security, fisheries and economic impacts, and land loss. Mitigating the effects of climate change will alleviate this burden on PICs and small island developing states, as noted in the IPCC's *Special Report on Global Warming of 1.5 °C,* but the impacts of climate change on their economies are depleting their capacity to make the necessary adaptations within a practical timeframe.[44]

Severe weather

PICs have a combination of high exposure to frequent and damaging natural hazards with low capacity to manage the results. Natural disasters arising from severe or shifting weather patterns impact industries such as the tourism sector while also impacting the already chronically under-resourced health systems of these nations. Adverse impacts from increasing storm activity, severe weather patterns and coastal sea-level rise inhibit development and retract years of development work, affecting the attainment of the UN Sustainable Development Goals (SDGs).

Further sea-level rise may result in displacement, with Pacific Island populations becoming amongst the first communities forced to migrate due to climate change, with legal and societal ramifications concerning refugee status. Sea-level rise also complicates maritime boundaries of fragile Pacific Island nations and their continued statehoods.

About two-thirds of the region relies heavily on agriculture and fisheries for their livelihood and food security, but a decline in crops and coastal sea life has had a particularly strong impact, notably

on subsistence livelihoods, which are common in PICs. Most critically, changing weather patterns and sea-level rise that impact the movement of fish have the potential to significantly impact the global fisheries sector.

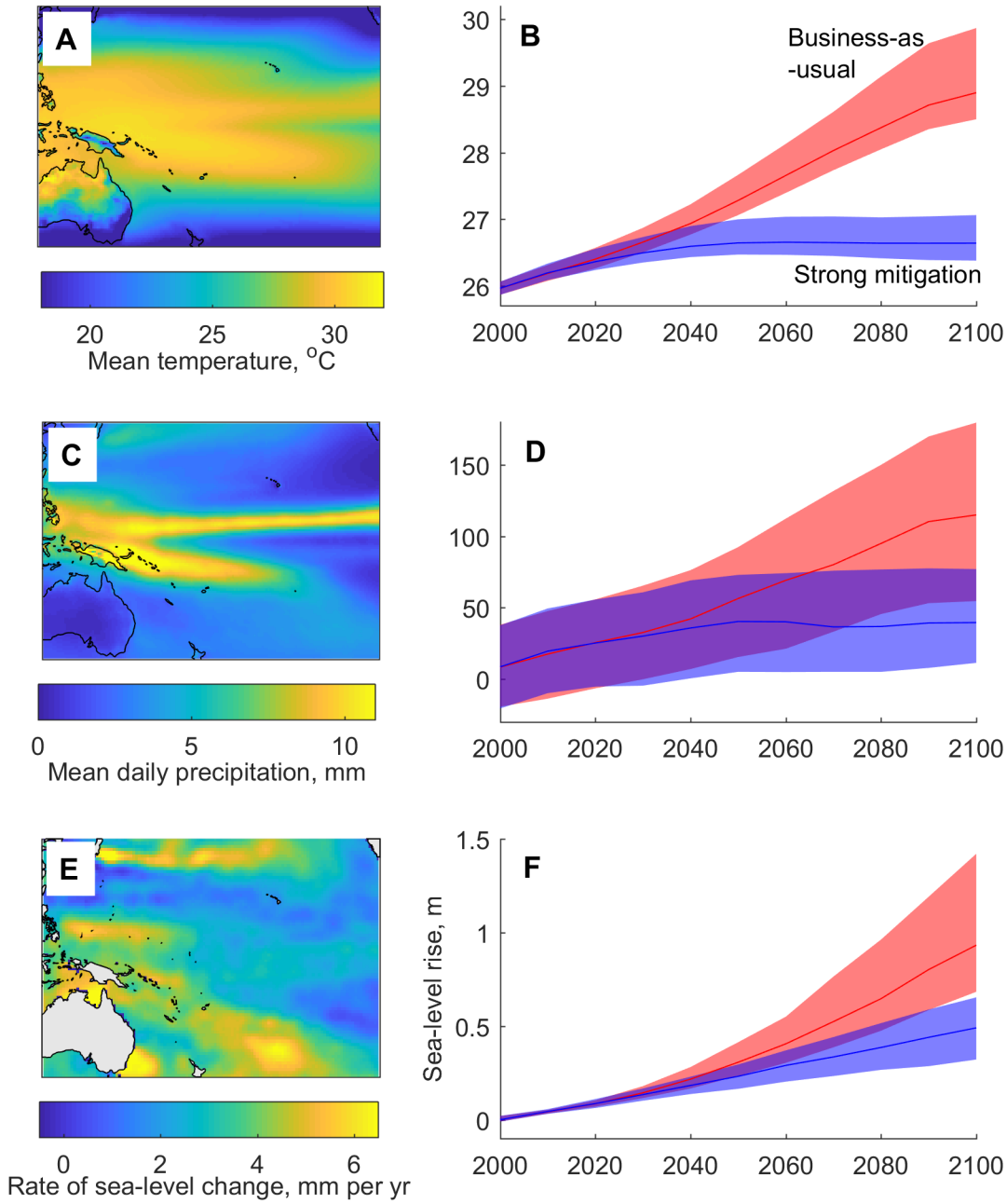

Figure 1: (A) Regional pattern of mean annual near-surface air temperature (degrees Celsius, 1993-2018); (B) Regionally averaged projection of mean annual near-surface air temperature (degrees Celsius) for business-as-usual (RCP 8.5, red) and strong mitigation (RCP 2.6, blue) scenarios; (C) Mean level of daily precipitation (millimetres, 1993-2018); (D) As in B but for daily precipitation (millimetres); (E) Rate of absolute sea-level change (millimetres per year, 1993-2018); (F) As in B but for sea level (metres) relative to 2000 baseline. (B, D, F) filled area represents 17-84% range of uncertainty with solid line the median. All regional averages are calculated as area-weighted means of full area displayed in A, C, E. Data: (A, C) ERA-Interim reanalysis[23], (B, D) CMIP5[70] database extracted from KNMI Climate Explorer (climexp.knmi.nl), both smoothed with 20 year sliding window. (E) Satellite altimetry from CSIRO

(https://research.csiro.au/slrwavescoast/sea-level/measurements-and-data/sea-level-data/). (F) Projections from Jackson & Jevrejeva (2016)[47] and Jackson et al. (2018).[46]

All nations need to recognise that mitigating the effects of sea-level rise and changing ocean conditions is vital to the maintenance of the planet. In a Brookings report published in *Nature*, however, it was noted that nationally determined contributions (NDCs), particularly those in industrialised nations, paid the least attention to the impact on oceans, focussing instead on emission control as the primary avenue for international cooperation.[38,80] Oceans play a critical role in climate mitigation and adaptation, and focussing on the impact on oceans and rising sea levels could open up an important avenue through which to drive a concerted effort in addressing climate change in future.

The remaining sections of this paper will focus on specific impacts of climate change and sea-level rise and illustrate how the early warnings provided by the conditions experienced in PICs can help to identify the global responses needed.

Climate change risk perception

Perceived risks affect how people will respond to climate change. Pacific Islanders' response to the perceived risk of climate change has been in response to direct impacts felt upon their livelihoods. These include directly felt impacts such as the destruction of homes from cyclones or floods. In contrast to the perception that climate change primarily threatens PICs through sea-level rise, the perception of inhabitants themselves indicate that threats from drought, flooding and extreme weather events pose a more impending threat. The most prominent impact of climate change felt upon by respondents in Samoa, Tuvalu and Tonga included the lack of sufficient water for human consumption and for crops (see Section 2.1).[12] These direct effects of physical hazards impact how understanding of climate change is perceived in the community and could also affect how policy decisions and mitigation strategies need to be communicated across all stakeholder groups to ensure that long-term challenges as well as short-term fixes are properly addressed.

2. Impacts of Environmental Change

2.1. Impact on Water Security

As well as the immediate threat from increased flooding, sea-level rise and climate change impact water security in PICs through altered temperature, rainfall patterns and saline intrusion into freshwater lenses. This threatens the security of human settlements, the health of the islanders and their capacity to maintain sustainable development.[89]

Average per capita freshwater availability in the Asia-Pacific region is the second lowest in the world and is associated with negative health implications, including vulnerability to heat stress.[76] Water security in Tuvalu stems from a lack of rivers and brackish groundwater, for example, while Nauru's location in the dry belt of the equatorial zone results in variable rainfall, with climate change projected to continue the trend of increased daily temperatures and variable rainfall patterns.[77]

Freshwater reserves are confined to groundwater lenses, small streams and rainwater, resulting in limited potable water resources on many islands.[90] Changes in precipitation and temperature affect available fresh water supplies through evaporation, runoff and soil moisture while the increasing water usage associated with economic development and urbanisation exerts additional pressure. [76] This combination – of climate change and urbanisation – threatens to drive water shortages, flooding, soil erosion and deterioration of water quality in coming years.[90]

Groundwater storage forms a significant portion of naturally occurring freshwater in PICs and is primarily recharged by precipitation. A reduction in rainfall leads to a reduction in the amount of freshwater that can be sustainably harvested and a reduced recharge rate of the aquifer. These effects are often exacerbated during times of drought and are likely to continue as the climate evolves, resulting in diminished groundwater supply for PICs.[43,90]

Of further concern for reef-based islands (atolls) is the ongoing risk to freshwater sources from seawater inundation.[43,68,69] Rising sea levels increase the flood potential of storm surges, king tides and wind-driven waves such that temporary coastal inundation may contaminate an island's freshwater supplies with saltwater. Additionally, sea-level rise in itself may eradicate a freshwater lens if the horizontal groundwater/sea water interface (controlled by mean sea level) rises to an impermeable geological layer forcing the two water bodies to mix.

Water's role in sanitation and health

The depletion of water resources and water degradation from salinization results in the use of less safe water sources that are more likely to be contaminated from microbial pollution (poorly maintained sanitation and open defecation resulting in water-borne diseases such as cholera) as well as agricultural and chemical pollutants in water supply catchments.[2,66] This, along with increased water salinization, exacerbates existing challenges around poor sanitation and disease.

The Pacific region has one of the lowest levels of sanitation globally. In 2015, only 51% of the regional population had access to improved drinking water sources while just 31% had access to basic sanitation. These were significantly less than the Millennium Development Goals' targets of 73% and 65% by 2015 for drinking water and sanitation, respectively.[90] Piped water coverage in 2015 was just 20% in the Pacific and is the lowest worldwide, with 34% of the regional population relying on water taken directly from rivers and lakes, which carries risks from water-borne diseases and parasites. Low per capita fresh water availability has negative health implications such as associations between hot days and hospital admissions arising from heat stress and diarrhoea; diarrhoeal diseases have been a significant cause of death in PIC children.[76,90] In Papua New Guinea, around 54% of diarrhoeal cases have been attributed to unsafe drinking water and poor sanitation. Figure 2 shows the impact of sanitation and drinking water on high diarrhoea mortality rates; Kiribati and the Federated States of Micronesia (FSM) also have very high rates of deaths from diarrhoea. Storm surges, which are predicted to increase in coming years, can exacerbate sanitation and water quality.

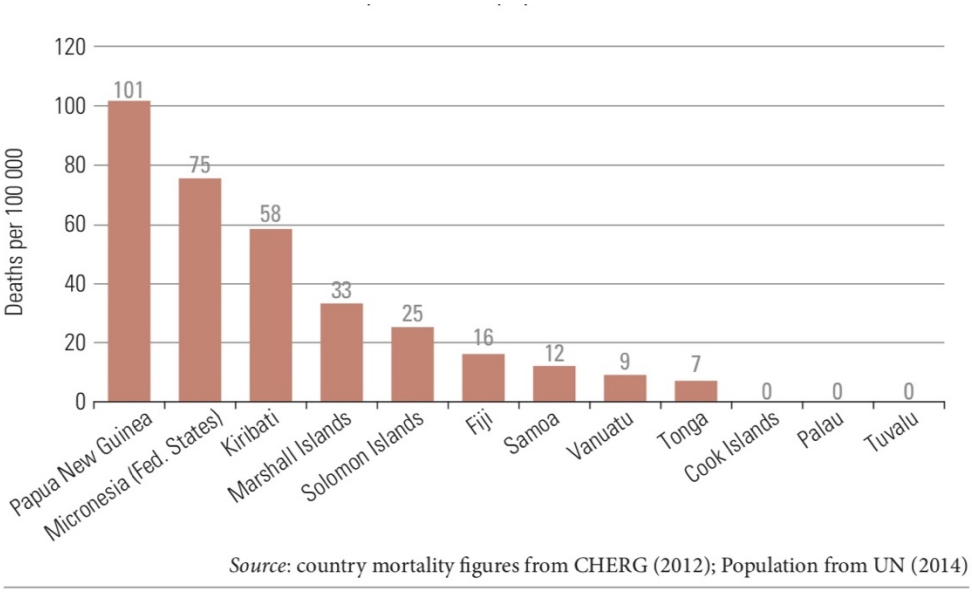

Figure 2: 2010 data on deaths from diarrheal disease per 100,000 population in PICs.[90] (Reproduced with permission from WHO)

2.2 Impact on Fisheries

Fisheries are a vital part of the economy in the Pacific region, supporting livelihoods, revenue, development and food security.[17] Many island atolls (such as Kiribati) rely solely on the sea as a source of livelihood and revenue as the porous soils on land limit agricultural productivity.[2]

The global importance of the fishing industry in PICs cannot be overstated. Fish is an important source of protein and micronutrients, supplying more than 3.1 billion people worldwide with 20% of their protein needs.[30,39,53] Due to their wide geographical range, PICs encompass approximately

28% of global exclusive economic zones (EEZs), which include some of the most productive tuna fisheries in the western and central regions.[4] In 2016, the combined harvest of tuna in the EEZs of PICs amounted to more than 1.5 million tons or 30% of the world's tuna catch.[48] Furthermore, key large nations utilize the oceanic tuna fisheries of the Pacific, including China, the United States, Japan, Taiwan and South Korea, with the tuna market making a significant contribution to their economies.[45] In the global fisheries and aquaculture market – which is worth around US$42 billion and supports the livelihoods of 660-820 million people (amounting to 10-12% of the world's population) – any negative environmental impacts on PIC's aquaculture will have wide ranging global effects.[30,53,62,72]

Fishing is not the only major source of internal revenue and employment at the local level. The sector is also an important contributor to the national economy. In Kiribati, fishing license fees accounted for 43.2% of government revenue and 26.6% of GDP in 2002, for example.[27] For some PICs, up to 84% of their revenue is generated through fishing licenses while the addition of onshore fish processing has led to the creation of 23,000 jobs across Fiji, the Marshall Islands, Papua New Guinea and the Solomon Islands in 2015 – nearly double the number associated with the industry in 2008.[32,73] The rise in employment in this sector is positive from a development perspective as it provides an avenue for society in these countries to function and maintains the health of the population through enhancing food supply and providing a constant and meaningful income stream, but it leaves them very vulnerable to climate change impacts.[2,58]

Figure 3 shows the relationship between the share of fisheries to GDP and the Human Development Index for 21 PICs.[8] Among low HDI countries, Tokelau, Tuvalu and the Marshall Islands depend heavily on fisheries for their national income, making them extremely vulnerable to impacts of climate change on the ocean environment. Conversely, those states with a lower percentage of shares in fisheries appear to have generally higher HDI indicating that they are likely to have greater resilience, though this may preclude secondary benefits of the fishing industry to the wider national economy.[53]

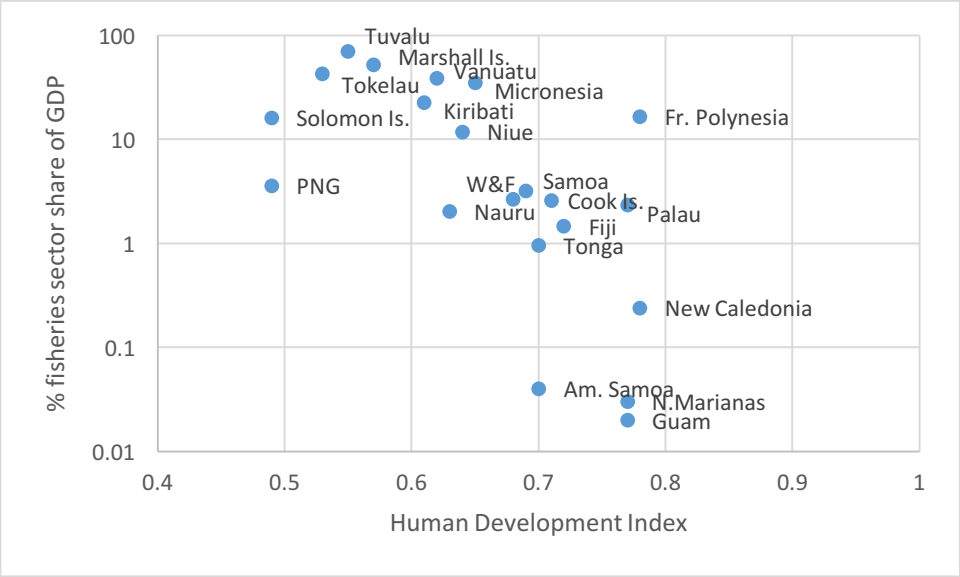

Figure 3: Fisheries sector share on a logarithmic scale of GDP for Pacific Island Countries (2013) versus Human Development Index. Data from Lam et al. (2016).[53] All countries data point is nearest value to left of label, except Wallis & Fortuna, which is to the right. (reproduced under CC-BY licence)

Risks to fisheries

The long-term viability of the fisheries industry in the Pacific, and the livelihoods and economies it supports, is a serious concern in the face of climate vulnerability and overfishing, particularly as global fish stocks become increasingly depleted. While attempts have been made to protect key ecosystems such the Phoenix Islands Protected Area (PIPA), which covers 410,500 km^2 and is one of the world's last intact coral archipelagos where tuna spawn, 30% of commercial fish stocks are considered overexploited with stocks in the Western Central Pacific being either fully- or over-fished.[30,58,72]

Maintaining sustainable development

These facts are concerning in light of SDG 14, which promotes the conservation and sustainable use of the oceans, seas and marine resources and will require a major focus on sustainable partnerships to manage fisheries in line with SDG 17 (partnerships for the goals); developing North-South and South-South cooperation is vital. Small-scale fisheries also play a crucial role in poverty reduction and food security, yet are often overlooked and undervalued in management and policy strategies.[42, 67,78]

The Pacific Islands Forum Fisheries Agency (FFA) is primarily involved with economic and policy aspects of the fisheries sector: its focus has been to strengthen capacities and maintain solidarity of its Pacific Island members, so they can manage and develop sustainable tuna fisheries. It has assisted member states with the Western Central Pacific Fisheries Commission (WCPFC), a network of stakeholders involved with the Pacific tuna fisheries that includes the US, Japan and China, among others. Management reforms remain a top priority to PICs including reaching consensus on management measures to reduce fishing mortality, a parameter used in fisheries population

dynamics, which can result in the loss of fish from the stock due to fishing activities in an equitable way.[31]

Case study: Tuna stocks and El Niño

Climatic conditions influence the location and volume of tuna stocks. In particular, the El Niño Southern Oscillation (ENSO) at yearly scales and the Pacific Decadal Oscillation (PDO) at decadal scales modulate the sea-surface temperature in the Pacific. The survival rates of larvae, their subsequent recruitment and the location of the best habitats for tuna species are all subject to climate variability. If current long-term warming trends continue there is expected to be an 89% negative impact on the maximum revenue potential (MRP) of fishing countries worldwide (170 countries). The impact on revenue streams resulting from changes in the location of prime fishing grounds will be felt most acutely in the Pacific with the greatest negative impact in the EEZs of the central Pacific.[48] Tuvalu and Kiribati are likely to see reductions in their maximum catch potential (MCP) of 79% and 70%, respectively, by 2050 under a business-as-usual emissions scenario.[53] This is likely to have a stark impact on PIC economies as there are few alternatives to fisheries as a major source of income.

2.3 Impact on Agriculture and Food Security

With fisheries and the fishing industry under threat, land-based food production is becoming critically important to PICs, but this is also vulnerable to changing environmental conditions. Food production is reliant on seasonal rainfall – altered rainfall patterns affect the abundance and distribution of crops.[85] This can have long-term effects on the economies of many Pacific Islands, particularly those more heavily dependent upon agriculture such as Papua New Guinea and the Solomon Islands, where, respectively, 69% and 68% of the islanders are employed in this sector.[5]

There is historical evidence of economic losses to the agriculture sector associated with climate. In Fiji, for example, prolonged changes in rainfall during the 1997-1998 ENSO event incurred losses of FJ$104 million to the sugar cane industry alongside other agricultural losses and livestock deaths amounting to FJ$15 million.[28] Extreme weather events have the potential to dramatically alter Pacific nations' sustainability. In 1990, Tropical Cyclone Ofa turned Niue from a food exporting country to a food import-dependent country for the subsequent two years (see Sections 2.3 and 2.6).[6] Projections of expected losses to the agricultural sector from climate change impacts for 2008-2050 are US$132 million, US$10 million and more than US$375 million to Papua New Guinea, the Solomon Islands and Fiji, respectively, for various crops.[79]

The decline in food security impacts social and economic development, hindering the attainment of sustainable development for PICs, in particular the attainment of SDG 2, which aims to end hunger, improve nutrition and promote sustainable agriculture.[78,79] Furthermore, as Pacific Islands transition from subsistence living to a more commercial food system dependent on foreign imports of food and a cash economy, their economic independence will decline.[56]

Biodiversity and resilience to climate change

Traditional crops can help to mitigate and manage climate change adaptation. For many coral atolls, pandanus trees planted along the shorelines help hold the soil while composting taro patches prevents seawater intrusion.[29] These crops are also more resilient to the detrimental effects of climate change, but shifting land-use agricultural practises are threatening this as well as causing dietary shifts. Exchanging local food crops for the generic production of cash crops is likely to result in biodiversity loss; in Kiribati, for example, pandanus and breadfruit trees have been cleared to make way for coconut production while labour has shifted from taro pits to copra production.[20] In the 1960s, strip mining in Nauru resulted in the degradation of 80% of the island's land and this is still limiting agricultural opportunities today, resulting in a heavy reliance on food importation (see Section 2.3 below).[77] Export and cash crops such as coffee plantations in Papua New Guinea are highly susceptible to global warming, particularly due to rising temperatures in the highlands.[16] Coastal flooding and erosion have also negatively impacted food production in the region, and numbers of pollinators and other key species will likely decline.[56,83]

Dietary shifts

In response to evolving food security, Pacific Islanders' diets have shifted from traditional produce to increased consumption of (often imported) processed and refined foods. This has been implicated in a significant increase in the rates of non-communicable diseases (NCDs) such as obesity, hypertension and cardiovascular disease (see Figure 4). The number of people in PICs suffering from diabetes has increased in recent years and is among the highest in the world, compounding the health of populations already dealing with high incidence of communicable diseases.[33,87,100] The burden of both categories of disease adds to the challenges faced by the under-resourced health systems in these countries. NCDs account for 60-80% of all deaths in the region, impacting productivity and years of potential life lost (YPLL). The diagnosis and treatment of chronic diseases such as diabetes and cardiovascular disease consume a large percentage of limited public resources such as treatment, and these populations are becoming increasingly vulnerable to negative health effects as their natural infrastructure deteriorates, while their poverty prevents them from accessing mitigations or healthcare services.[80,85]

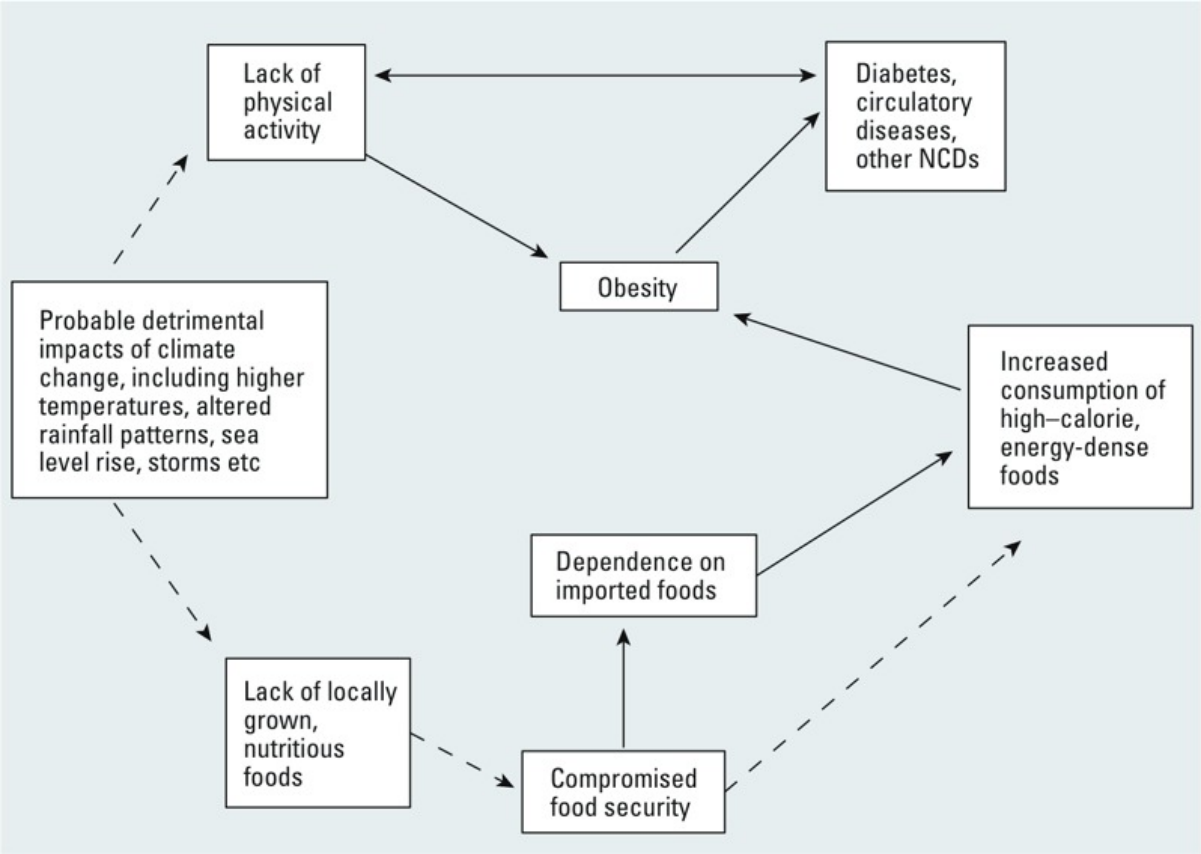

Figure 4: Conceptual model depicting pathway between climate change and health from McIver et. al (2016)[57] (Reproduced with permission from Environmental Health Perspectives)

Gender issues in food and water security

Women account for 56% of annual small-scale catches in PICs' fishing industry, equating to a revenue of US$110 million.[42] This informal sector of the economy is critical for sustainable food security. However, women's roles may be negatively impacted by the loss of aquaculture and agriculture through changing practices driven by climate change and economic transition to more "modern" patterns of living. Traditionally, women grow food in home gardens or harvest fish and sea life from coastal areas, which are more vulnerable to climate change impacts, while men tend to be involved in producing cash crops or to engage in offshore and deep sea fishing for commercial purposes. Climate change impacts could reduce their ability to provide food for their families, increase their workload, and increase their reliance on imported food sources that are not necessarily nutritious as well as reducing their family's income, impacting their overall well-being.[79] Involving women in water management and sanitation has been recognised globally and efforts by national governments in PICs have been implemented. The Tonga Community Development Trust has developed guidelines to support the operation of women who are managing the sustainability of rainwater harvesting programmes.[66]

2.4 Impact on Tourism

With fisheries and agriculture under threat as secure economies, tourism is becoming increasingly important to PICs. In Tonga, tourism is the single largest revenue source – five times greater than agriculture and fisheries combined, and in Fiji replacing its primary economy: the export of sugar.[99] In 2006, visitor spending as a percentage of GDP was between 10-50% for Vanuatu, Samoa, Fiji and French Polynesia.[84]

The interrelationships between tourism, development and climate change present a significant policy dilemma, especially for developing states. Tourism can contribute towards economic development and has been promoted by organisations (such as UNWTO) as a means of poverty reduction. If properly developed, it can be a "quick win" option in overcoming economic and social shortcomings, allowing an acceleration of a state's integration into the global economy. This perspective is divisive, however, due to the potential for non-uniform financial benefits from the industry across the rest of a state's economy, both geographically and in terms of development. Furthermore, the long-term benefit of tourism programmes to the overall positive development of regions remains poorly evaluated. Tourism can cause significant environmental degradation and lead to insecure seasonal variability of employment, wages and investment.[40]

Additionally, tourism development often results in a concentration of infrastructure and assets along the coast.[96] As coastal areas are also at the most risk from sea-level rise and extreme weather events, increasing storm severity and natural disasters can negatively impact tourism infrastructure and visitor numbers. For example, the Samoa tsunami of 2009 affected tourism arrivals for three years during the subsequent rebuilding process.[99] Tourism can drive resilience awareness and investment, however: operators of tourist resorts in Fiji have invested in preparedness for extreme events and have adapted to potential climate change impacts.[11] Where tourism contributes significantly to the state economy, it has power to drive climate adaptation/mitigation measures. In Fiji and Vanuatu, significant progress has been made through the creation of a tourism-climate change policy network.[10]

2.5 Impact on Energy Security

A further factor impacting the ability of PICs to invest in large-scale infrastructure projects and transformation of their economies is accessibility to energy. The relative geographic isolation of PICs and the lack of regional fossil fuel reserves make them dependent upon imported fossil fuels to meet their energy needs for transport, electricity, businesses and households. Depending on their level of development, some PICs are still fighting for energy access while others struggle with energy security. Their dependence on energy imports makes them highly vulnerable to rising/fluctuating prices, which can impinge negatively upon their national development strategies – exemplified in the Marshall Islands where at least 10% of the country's GDP is spent on importing fossil fuels for electricity generation – and challenges their capacity to meet the targets of SDG 7 (access to affordable and clean energy).[63,92]

Governments and development partners continue to prioritise the development of power networks through subsidies and the commitment to ambitious renewable energy targets (see Table 2). Whilst a high level of awareness of and vulnerability to climate change ensures that PICs aspire to lead the global movement towards net zero emissions, most islands generate a low proportion of their energy from renewable sources. Exceptions include Tokelau, which is heavily solar powered, and Fiji and Papua New Guinea, which both produce hydro-electricity. Other renewable energy forms such as copra (coconut oil) are also being considered, and the populated islands of the Marshall Islands: Majuro and Ebeye are upgrading their electricity grid and increasing solar and wind penetration on this grid. The Marshall Islands have developed an ambitious strategy to become carbon-neutral by 2050 which, if successful, may provide a case study on evaluating interventions that can be translated to other, non-PIC coastal nations while encouraging other countries to follow suit.[63]

While mitigation for PICs is largely symbolic – their carbon emissions account for just 0.12% of global output – the switch to renewables should have positive impacts for economic development, in turn improving individual incomes, and providing additional funds for investment in health and education.[13]

					Renewables		
Country	Fuel supply stock (2015), equiv. days	Electrification level (2015) %	Modern cooking source access (2015) %	Modern lighting source access (2015) %	Current share % (2014)	Target share % (based on NDCs)	Target date
Cook Islands	83	99	100	100	50	100	2020
FSM	105	65	18.7	64.5	4.3 (2009)	30	2020
Kiribati	34	65	18.7	63.3	0	28	2025
Marshall Islands	124	90	59.4	89.9	5 (2013)	20	2020
Nauru	302	99	91.0	99	0.5	50	2020
Niue	60	100	91.4	100	0	100	2020
Palau	24	100	100	100	8	45	2025
Samoa	49	98	28.5	97.9	20 (2012)	100	2017
Solomon Islands	90	43	7	85.5	0	100	2030
Tonga	35	96	53.8	100	9	50	2020
Tuvalu	39	98	49.1	97.6	50	100	2025
Vanuatu	110	33	13.5	43.1	15	65	2020
Fiji	89	92	41.7	92.4	19 (2013)	100	2030
Papua New Guinea	N/A	20	8.4	24.6	>40	No new target	

Table 2: Fuel security, electricity, cooking, lighting access and renewables data for PICs. Adapted from Dornan (2014)[13] MPFD (2016)[75] and IPESP Progress Report (2017)[66]

Challenge: Transport, energy and decarbonisation

Due to their geographical remoteness, dispersion and small populations, PICs have considerable challenges with connectivity and transport that affects their ability to access energy and their requirement for it.

The transport sector accounts for 70% of fossil fuel use in PICs and is also vulnerable to the effects of climate change, with temperature changes, sea-level rise, storm surges, floods and landslides damaging pavements, highways and bridges, roads and infrastructure, including by the erosion of road foundations and bridge supports. Development projects within the region need to and do take into consideration future sea-level rise and make adjustments for climate adaptation when both engineering and maintaining structures.[1]

A current pilot project is underway in the Marshall Islands to test the use of solar powered electric vehicles as an alternative source of transport that will help the country's transition away from fossil fuel usage. Additionally, the Marshall Islands is encouraging efforts to decarbonise international shipping. Better data, however, is needed to determine what proportion of fossil fuels is used for land transport as noted by the Marshall Islands' 2050 Climate Strategy.[63]

2.6 Finance and Economic Investment in the Pacific Islands

Climate change impacts cost PICs dearly. Vanuatu, Niue and Tonga have the largest average annual loss (AAL) from natural disasters for the region, with 6.6%, 5.8% and 4.4% of their national GDP, respectively, and are amongst the countries with the highest AAL globally.[95] Increasing disaster risk financing and providing assessment tools to assess exposure to natural disasters is imperative to future economic investment and development in the region.

Projects to address this have been initiated by the World Bank through the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), which incorporates the Pacific Risk Information System (PacRIS) database of more than five million public and private buildings for hazard modelling. This allows for the assessment and severity of an event in terms of potential fatalities and injuries as well as estimated damage to buildings and infrastructure such as health clinics and hospitals. In 2018, Tonga received the largest and most rapid pay-out (within seven days) in response to Tropical Cyclone Gita, a Category 4 storm that resulted in severe winds flattening buildings, and the strongest cyclone to hit Tonga since 1982 from the programme.[97,98] Developing such infrastructure and programmes can assist in mitigating natural disasters attributed to anthropogenic climate warming and can assist a country to rebound quickly from such disasters that might otherwise take years of development work and growth.

Lack of technical capacity in many PICs, however, constrains efforts to develop quality infrastructure or economic development projects and impacts their ability to access funds that would otherwise be available. Currently, most climate finance is provided through multilateral agencies that provide technical support, but PICs often still lack the capacity to implement projects. Policy measures are being taken to address these issues, including investing in technical capacity to

access climate funds, developing sector-specific plans to attract resources, and aligning national development plans with external aid and national budgets. Additionally, progress has been made in how domestic and external resources are utilized with assistance from the Pacific Islands Forum Secretariat (PIFS) to coordinate the implementation of the *Forum Compact – A Pacific Regional Enabling Mechanism to Achieve Sustainable Development,* but building capacity in PICs should be a priority for the future.[78,80]

3. Priority Challenges

3.1. Maintaining Human Health in PICs

The vulnerability of PICs to environmental change puts their populations' health and well-being at risk with morbidity and mortality rates impacted. Constant damage from extreme weather hinders the ability of a health system to rebound effectively and threatens a decrease in the quality of life for affected populations.[88]

Case Study: Impact of natural disasters on health and health systems

In 2014, flash floods in the Solomon Islands resulted in 21 deaths and an estimated 1,209 years of potential life lost (YPLL). Acute morbidity was noted to be more prevalent in older age groups than mortality, with near-drowning and hypothermia accounting for the majority (48%) of injuries incurred, followed by soft-tissue injuries and fractures or dislocations. Three out of nine health clinics were damaged, forcing hospital staff to work extensive hours with fewer resources during a time of increased patient demand. Cases of diarrhoea peaked with 3,867 cases identified – significantly higher than in the previous year. Additionally, there were 8,584 cases of infectious diseases and 10 resultant deaths, with 346 cases of dengue, and 2,667 cases of malaria.[60]

The increasing frequency of extreme weather events impacts the ability of health systems to return to a normal state before the next natural disaster comes into question, reducing the resilience of health systems and their ability to rebound after disasters and may result in total failure or collapse. As projections indicate a likely increase in frequency and intensity of weather, this will place additional strain on health systems that are already under-resourced and under-manned.[88] Limited human resources and capital, technical capacity, data, information systems, infrastructure and finance all make it challenging for PICs to retain or attract qualified healthcare professionals, resulting in expert labour shortages and an increasing health burden.[57] Lack of training and education infrastructure on the islands means that PIC nationals generally train as health professionals overseas. The overwhelming challenges and under-resourced health systems at home then provide little incentive for trained professionals to return or stay, resulting in a vicious cycle that degrades the technical and institutional capacity of PICs health systems and places their attainment of SDG targets on health at risk.[77]

Health targets are not helped by the poor state of sanitation in many PICs, which is a combined consequence of low economic development, lack of capacity or incentives to invest in infrastructure, likelihood of severe weather events damaging any infrastructure that is developed, and general water scarcity and insecurity exacerbated by climate change.

Financing health

Like most poor countries, PICs have low public health expenditure and rely heavily on external donors, whilst high burdens of disease eat up a large proportion of the total development money

they receive.[25] A World Bank study in 2000 found that the cost of treating NCDs in PICs was between 39-58% of total health expenditure.[89] Limited human and financial resources are barriers to scaling up and implementing sustainable adaptation to long-term national priorities.[26] The total amount of Official Development Assistance (ODA) to PICs doubled from 2002 to 2012, amounting to almost US$2 billion from US$915 million; although as a percentage of GDP, assistance decreased from 12.5% in 2000 to 6.3% in 2014. Additionally, some forms of aid from development partners consist of uncoordinated projects that exacerbate fragmentation and reduce effectiveness, and for some countries were the only form of aid received.[86] Determining whether the outcomes and outputs of these projects increase resilience to climate change are contingent upon whether such issues remain national priorities after completion, and are also impacted by limited political will and leadership as well as financial and human resources.[26]

Recommendation: An urgent need to strengthen the resilience of health systems in PICs

Health systems are vital to human health, especially in times of natural disasters, but as they are exposed to increasing storms, floods and other extreme events, their ability to rebound is impacted (see Figure 5). In the Pacific Islands, many health system infrastructures are located along the coast and are particularly susceptible to storm surges created by tropical cyclones.[96] The *WHO Operational Framework for Building Climate Resilient Health Systems* discusses the capacity of such health systems to protect human health in an unstable and changing climate.[88] Their resilience needs to be strengthened in response to the stresses placed upon them from climate variability and change; they need to cope and maintain their essential functions in order to assure their continued performance. However, the magnitude and frequency of such shocks are threatening to push health systems to collapse or failure, as depicted in the conceptual framework below. If they are not able to adapt and become more resilient, it will likely negatively impact human well-being in PICs.

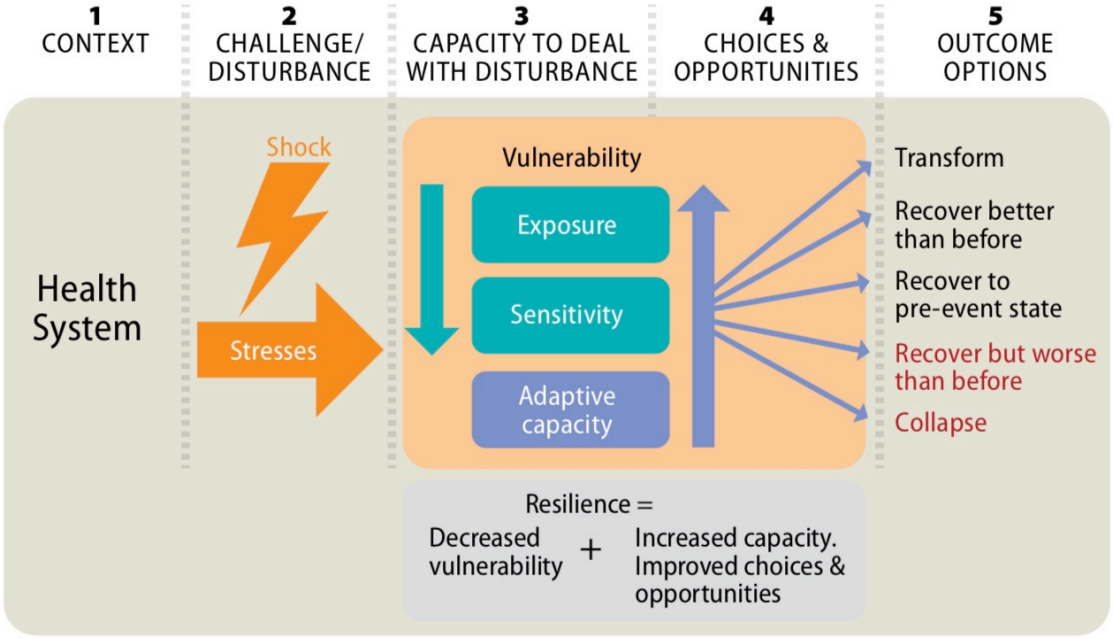

Figure 5: WHO Conceptual Framework for Resilience. Adapted from Defining disaster resilience: A DFID approach paper (2011) [88] **(Reproduced with permission from WHO)**

3.2 Sovereignty, Land Loss and Displacement

A second major challenge facing PICs that might indicate an early warning of similar impacts on larger islands and coastal regions is the impact of sea-level rise on land security, sovereignty and the threat of displacement – both temporary and permanent – for large numbers of the population. Long-term sea-level rise threatens to impact sovereignty in two ways. First, as mean sea-level rises, so too does the level of low tide. This causes the loss of fixed markers and alters baselines, which could result, in theory, in portions of coastal land (e.g. a spit or peninsula) falling outside a country's territory despite being connected to the mainland. If baselines were redefined according to new fixed markers further towards the shore at higher elevation, the various limits of each maritime zone would also move landward, resulting in a loss of marine territory.[37]

If an entire island were inundated, as may be the case for a small number of Pacific (and other global) islands, there is no current framework for defining a state without a landmass. In 2016, the Marshall Islands passed comprehensive new legislation, the Maritime Zones Declaration Act, detailing its maritime boundaries with extensive maps and geographical coordinates on the baseline and limits of its government waters and EEZ. The Cook Islands, Fiji, Kiribati, Nauru, Niue, Palau and Tuvalu followed suit by all declaring the outer limits to their EEZs.[36,71] These pre-emptive measures were taken by each nation to safeguard their future sovereignty and economic stability.

While this decision may at first appear unusual, the reasons for it are clear within the framework of the United Nations Convention on the Law of the Sea (UNCLOS). This convention provides an international framework for countries to measure their territorial seas, contiguous zone, EEZ and

continental shelf. At present, all of these defined areas are measured relative to a baseline – a series of geographical lines joining physical markers along a nation's coast that are exposed at low tide. The action taken by the aforementioned nations protects their ownership of their maritime zones and economically beneficial marine resources from the reality that physical maritime boundaries are dynamic, not fixed.[36]

The action taken by the Marshall Islands – and other islands that followed its lead – emphasises their real concern for long-term sea-level rise. This is particularly important as sea levels are predicted to continue to rise for hundreds of years after global emissions are stabilised or reduced and may render many countries, or large areas of them, uninhabitable.[18] It is important to note that challenges to maritime zones impact all coastal nations, from Florida in the US and the Gulf of Mexico to Bangladesh and the Netherlands,[37] along with those with overseas dependencies and territories of many larger nations such as the United Kingdom and France.

Land loss and displacement

The potential for parts or the entirety of a state to be submerged, or made uninhabitable through other climatological factors (temperature, precipitation, wind, etc.), risks internally or externally displacing its citizens. Internal displacement is often a first step for communities responding to the temporary or permanent loss of habitability of their local region, followed by cross-border displacement to another island or to mainland neighbours.[37] Displacement within the Pacific Islands, with communities being able to be resettled within their customary lands, engenders fewer social and environmental impacts than displacement further afield, but this is neither always possible nor likely to be sustainable long term if the islands on which they settle also come under threat.[52]

For PICs, cross-border migration is likely to have negative impacts on the health and livelihoods of resettled people, exposing them to challenges, including landlessness, unemployment, homelessness, social marginalization, food insecurity, reduced access to common-property resources and increased morbidity.[14,15,94] Resettlement typically entails loss of income, impoverishment, mental illness, inability to retain cultural ties, or to preserve a strong sense of self and identity, and increases exposure to social and environmental stresses.[9,15,84] In PICs, cross-border relocations have exposed those affected to impoverishment and social fragmentation.[55]

A further issue related to cross-border displacement is that of a person's legal status. At present, there is no formal recognition of climate change refugees. Refugee status is only conferred upon people who are at risk of persecution in their place of origin, leaving displaced populations with a lack of legal recognition that has a wide range of negative implications.[35] The Nansen Initiative is a protection agenda that seeks to build consensus between states on how to best address cross-border displacement caused by sudden and slow-onset disasters, access to services and medical care may be strictly limited; unemployment and food insecurity may result in increased morbidity and mental health problems.[59] From the host-country's perspective, cross-border displacement may overburden resources, public services and their financial and health systems.

Recommendation: Establish legal protection for climate change refugees

The timely urgent development of an international legal framework clarifying the status of climate change-induced refugees would help to mitigate the challenges facing the populations of small island states that have only marginally contributed to climate change, but who are compelled to relocate to another country due to environmental destruction or land inundation. Work is currently being done in this sphere. Policy options include disaster risk reduction, climate change adaptation, facilitating migration, planned relocation and, critically, assistance and expertise that will enable such policies being put into action.[35,59]

4. Developing Capacity in Pacific Island Countries

4.1 Human Capital

A key challenge for PICs in developing climate change capacity is limited human capital, largely due to their small populations.[57] Limited local educational opportunities encourage a brain drain in which potential innovators and entrepreneurs leave to study overseas and, once qualified to do so, pursue better opportunities outside the region. Combined with limited financial and technological resources available at the individual country level, developing and managing public or planetary health surveillance systems is challenging. Such systems are, however, necessary to provide evidence for the validity (or otherwise) of policy recommendations regarding mitigation and adaptation.

Monitoring systems and multinational collaboration would help provide insight into potential mitigation and adaptation co-benefits, for example the potential of the blue economy to sequester carbon through mangrove, seagrass and coral protection, as well as replanting that protects coastlines from floods, improves water quality through filtering processes, improves tourism opportunities through greater marine biodiversity, and improves robustness of local near-shore fishing industries. But, the data on this needs to be strengthened and lessons from it identified, particularly those that might inform policy in other contexts and/or on a wider scale.

Internalising human investment and developing educational opportunities in order to build expertise from within small islands, instead of relying on external forces, is vital for sustainable development and contextualising the available solutions. Increasing international collaboration with PICs and building cross-collaboration between PICs through, for example, centres of excellence, may increase the human capacity of such island nations and help to build an evidence base that can be used to inform not only their own policy decisions, but those of the international community more widely.

4.2 Building Data Capacity

Data capacity may benefit, in the short term at least, from focussing on building capacity in surveillance and data collection that will provide the strong evidence base needed to assess climate change impacts and inform the policy responses needed to address them. Robust data is required to record observations (e.g. on changes to climate, incidence of disease and impact on economy) to extrapolate trends from these observations, and to build numerical models that can be used to test alternative strategies. Qualitative evidence, including expert judgment and personal testimonies, is also needed to help shape what data is entered into the models, and the models are integrated.

Good data collection and analysis are critical to making good decisions; however, the lack of robust, high-quality data inhibits PIC governments, research institutions and the development groups currently working with them from making statistically valid conclusions. Tracking the attainment of

SDGs, for example, requires well-organised and continuous cross-sectoral data-retrieval systems and capacity for data collection and management.[77] Both the quality and quantity of data are critical when linking anthropogenic climate change to sectoral changes and stress on governance structures.

To give a specific example, at present, Papua New Guinea and the Solomon Islands between them host the greatest malaria burden in the region, accounting for 92% of cases and incidence is likely to increase in the future.[91] The *Special Report on Global Warming of 1.5 °C (SR15)* states that "while any future increase in global warming will affect human health (*high confidence*)…Risks are projected to increase for some vector-borne diseases, such as malaria and dengue fever (*high confidence*)."[44]

Fully modelling future increases, however, will depend on complete data that is able to correlates climate data (particularly local warming trends) with corresponding public health surveillance data, but such a complete picture is limited. Proving that a causal chain of changes in the climate system results in a particular societal outcome requires advanced statistical analyses to account for natural climate variability, societal changes and technological adaptation.[101] Such integrated models are critical: correlation does not necessarily mean causation, and getting to the bottom of the actual causal agent will be key to ensuring investment and adaptation policies are being targeted efficiently.

While the current evidence base is not strong, emerging projects and international collaborations such as the Australian Department of Foreign Affairs and Trade-funded malaria climate application project (MalaClim Application) have been attempting to address this by correlating climate and malaria data in the region. However, while sufficient data has been available for the Solomon Islands, the project has so far been unable to extend analysis to other regions due to limited surveillance mechanisms, including technological and human resources, on other Islands.[65] The Marshall Islands 2050 Climate Strategy recommends investment in data collection for the establishment of baseline data for sectors such as transport and electricity, noting uncertainties around the data on fuel used for electricity generation, for example, or on the proportion of imported fuel used for domestic land transport, that inhibit a full analysis of the situation.[63]

4.3 Finding an International Voice on Climate Change

Improving the capacity of PICs to produce robust, clear and well-analysed data – including robust models of future impact – may help to give them a louder voice in international forums and ensure their concerns are heard. Working together to pool resources and to combine their data into coordinated and consistent messages will also increase their reach. The establishment of the Alliance of Small Island States (AOSIS), comprised of small-island and low-lying countries including many PICs, has made a vital contribution in pooling together the resources of many Small Island Developing States (SIDS) and amplifying their voices within the UN and at Paris Climate Agreement negotiations.[7]

AOSIS's success culminated in 2017 when Fiji became the first small island developing state to provide the president of the annual UNFCCC Conference of Parties (COP 23). In his opening address and subsequent remarks, H.E. Mr Frank Bainimarama made clear the need to "focus on the most vulnerable people and the most vulnerable nations… to emphasise that their interests are your interests" and highlighted the launch of an Ocean Pathway to ensure the ocean becomes integral to the UNFCCC process by 2020.[21] By establishing partnerships with the European Commission, Australia and the United Nations Development Programme (UNDP), AOSIS has been able to design a targeted programme of support that has resulted in the AOSIS UNFCCC Support Programme. SIDS have also been able to utilize UNDP's accreditation with the Global Environment Facility (GEF) to develop a multi-year environment and climate change portfolio.[74] AOSIS will need to continue to play a concerted role for PICs and other small island states on the importance of oceans in addressing climate change at the global level.

Case study: PICs in global leadership – The Taputapuātea Declaration on Climate Change

A good illustration of the benefits of regional cooperation between small island states is the Taputapuātea Declaration on Climate Change, which was signed by the leaders of seven Polynesian states and territories on 16 July 2015, prior to the UNFCCC COP 21 in Paris later that year. The agreement emphasised shared cultural heritage and the unitary nature of Polynesian populations and stated their desire to tackle the impacts of climate change through mutual support and development. It also aimed explicitly to lobby the UNFCCC on obtaining international commitment to remain below 1.5 °C.[41,64] The Taputapuātea Declaration had a direct influence on the drafting of the Paris Agreement: in February 2016, French President Francois Hollande stated, "COP21 [was] the Paris Conference; perhaps we should reassess this…saying…it is also the conference of the Marae of Taputapuātea."[54]

Additionally, PICs have taken a leadership role in ratifying amendments to address climate change mitigation. The Marshall Islands, for example, played a key role in convening a progressive group of countries for the High Ambition Coalition that has ensured the Kigali Amendment to the Montreal Protocol addressing ozone depletion will be ratified.[82] The Marshall Islands is also chairing the Climate Vulnerable Forum, a group of 48 developing countries, including Bangladesh and Rwanda, which are vulnerable to climate change. Such initiatives are pushing the power of collaboration as a driver for greater climate action and should be supported and strengthened in future.[19]

5. Conclusion

Section A5.1 of the *Special Report on Global Warming of 1.5 °C (SR15)* states that: "In the context of sustainable development, feasibility depends on enabling conditions."[44] This paper has offered a perspective on how small islands – as a whole and by specific sector – are currently affected by climate change and how these impacts are likely to develop in the future, giving an early warning to larger island nations and nations with high coastal-to-inland land ratios.

Issues highlighted include institutional capacity, policy and finance, multi-level governance, technological innovation and transfer, and changes in human behaviour and lifestyles. This list is unlikely to be exhaustive, and other challenges may well emerge. From a planetary health perspective, the complex web of interweaving issues affecting multiple levels of society, from local to regional levels at a variety of timescales, requires a full interdisciplinary approach that is typified by user-focussed needs assessments and resource provision.

The paper has also shown that PICs have an important role to play on the global stage. Their fisheries make a significant contribution to the global economy and the impact of climate change on the marine resources available and the governance structures surrounding this are likely to be considerable. Their vulnerability to climate change offers a window into what other nations should anticipate, while offering the opportunity to assess interventions in various sectors that can mitigate and adapt to climate change.

Finally, PICs are providing a critical voice within the international community that has recently been listened to and acted upon, of which the Taputapuātea Declaration provides a perfect example. The PICs perspective on planetary health and suitable solutions, therefore, provides a valuable framework for moving forward towards planetary health for all nations and populations in the future.

References

1. Asian Development Bank (2013) Climate Change and Transport. Manila: ADB. Available from: https://www.adb.org/sites/default/files/publication/30375/climate-change-transport.pdf
2. Asian Development Bank (2011) Food security and climate change in the Pacific: rethinking the options. Manila: ADB. Available from: https://www.adb.org/sites/default/files/publication/29078/climate-change-food-security.pdf
3. Asian Development Bank (2018) Economic and fiscal impacts of disasters in the Pacific. Manila: ADB. Available from: https://www.adb.org/sites/default/files/publication/415601/economic-fiscal-impacts-disasters-pacific.pdf
4. Gillett, R (2005) 'Pacific Island Countries Region', in Review of the State of World Marine Resources: FAO Fisheries Technical Paper 457. Rome: FAO. Available from: http://www.fao.org/3/y5852e/Y5852E07.htm#ch2.16
5. ADB. Rosegrant MW, Valmonte-Santos R, Thomas T, You L, Chiang C. Climate change, food security, and socioeconomic livelihood in Pacific islands. Manila; 2015. Available from: https://www.adb.org/sites/default/files/publication/175046/climate-change-food-security-pacific.pdf
6. Adger WN, Agrawala S, Mirza MMQ, Conde C, O'Brien K, Pulhin J, et al. 2007. Assessment of Adaptation Practices, Options, Constraints and Capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 717–743.
7. Alliance of Small Island States (n.d.). [accessed 2018 Oct 17]; Available from: https://aosis.org/
8. Anand S, Sen A (1995) Human Development Index: Methodology and Measurement. New York: Human Development Report Office. Available from: http://hdr.undp.org/sites/default/files/oc12.pdf
9. Asthana R (1996) Involuntary resettlement, Survey of international experience. *Economic and Political Weekly*, 31(24):1468–1475.
10. Becken S, Clapcott R. (2011) National tourism policy for climate change. *Journal of Policy Research in Tourism, Leisure & Events*. 3(1):1-17.
11. Becken S (2005) Harmonising climate change adaptation and mitigation: the case of tourist resorts in Fiji. *Global Environmental Change*, 15(4):381-393.

12. Beyerl K, Mieg HA, Weber E (2018) Comparing perceived effects of climate-related environmental change and adaptation strategies for the Pacific small island states of Tuvalu, Samoa and Tonga. *Island Studies Journal*, 13(1):25-44.

13. Boden TA, Marland G, Andres RJ. (2017) Global, regional, and national fossil-fuel CO2 emissions. Oak Ridge: US Department of Energy. DOI: 10.3334/CDIAC/00001_V2017.

14. Campbell J (2010) 'Climate-Induced Community Relocation in the Pacific: The Meaning and Importance of Land', in McAdam J (ed) Climate Change and Displacement: Multidisciplinary Perspectives. Oxford: Hart.

15. Cernea M (1997) The risks and reconstruction model for resettling displaced populations. *World Development*, 25(10):1569–1587.

16. CGIAR (2016) Climate change and Pacific island food systems: the future of food, farming and fishing in the Pacific islands under a changing climate. Available from: https://ccafs.cgiar.org/publications/climate-change-and-pacific-island-food-systems#.W8gCNRNKjow

17. Charlton KE, Russell J, Gorman E, Hanich Q, Delisle A, Campbell B, et al (2016) Fish, food security and health in Pacific island countries and territories: a systematic literature review. *BMC Public Health*, 16:285.

18. Clark PU, Shakun JD, Marcott SA, Mix AC, Eby M, Kulp S, et al. (2016) Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. *Nature Climate Change*, 6(4): 360.

19. Climate Vulnerable Forum (CVF) (2018) Let's support the world's most vulnerable nations – and their first carbon-free summit (Press Release) [accessed 2018 Oct 17]. Available from: https://thecvf.org/lets-support-the-worlds-most-vulnerable-nations-and-their-first-carbon-free-summit/

20. Connell J (2015) Food security in the island Pacific: Is Micronesia as far away as ever? *Regional Environmental Change*, 15(7):1299–1311.

21. COP23 (2017) 23rd Conference of Parties [Opening Statement]. Bonn: UNFCCC. [accessed 2018 Oct 4]: Available from https://unfccc.int/process/conferences/un-climate-change-conference-november-2017/documents/opening-statements-cop23/cmp13/cma12

22. Costello MJ, Cheung A, De Hauwere N (2010) Topography statistics for the surface and seabed area, volume, depth and slope, of the world's seas, oceans and countries. *Environmental Science and Technology*, 44(23):8821-8.

23. Dee DP, Uppala SM, Simmons AJ, Berrisford P, Poli P, Kobayashi S, Andrae U, Balmaseda MA, Balsamo G, Bauer DP, Bechtold P (2011)The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. *Quarterly Journal of the Royal Meteorological Society*, 137(656):553-97.

24. Dornan, M (2014) Access to electricity in small island developing states of the Pacific: issues and challenges. *Renewable and Sustainable Energy Reviews*, 31:726-735.

25. Ebi KL (2008) Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030. *Globalization and Health*, 4:9.

26. Ebi KL, Otmani Del Barrio M (2017) Lessons Learned on Health Adaptation to Climate Variability and Change: Experiences Across Low- and Middle-Income Countries. *Environmental Health Perspectives*, 125(6):065001.

27. EU (2005) Republic of Kiribati/European Commission Joint Annual Report 2003. Available from: https://ec.europa.eu/europeaid/sites/devco/files/joint-annual-report-03-cooperation-eu-kiribati-20050415_en.pdf

28. FAO (2008) Climate change and food security in Pacific island countries. Rome: FAO. Available from: http://www.fao.org/docrep/pdf/011/i0530e/i0530e.pdf

29. FAO (2011) Let's go local. Apia: FAO. Available from: http://www.fao.org/docrep/015/an763e/an763e.pdf

30. FAO (2014) The State of World Fisheries and Aquaculture. Rome: FAO. Available from: http://www.fao.org/3/a-i5555e.pdf

31. FFA Pacific Islands Forum Fisheries Agency (2017) 2016-2017 Annual Report. Available from: https://www.ffa.int/system/files/FFA%20Annual%20REport%202016-2017%20-%20low%20resolution.pdf

32. FFA Pacific Islands Forum Fisheries Agency (2016). FFA tuna development indicators. Honiara: FFA. Available from: https://www.ffa.int/system/files/FFA%20Tuna%20Development%20Indicators%20Brochure.pdf

33. Finucane MM, Stevens GA, Cowan MJ, Danaei G, Lin JK, Paciorek CJ, et al. (2011) National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *The Lancet*, 377(9765):557–67.

34. Fischhoff B (2007) Nonpersuasive communication about matters of greatest urgency: climate change. *Environmental Science & Technology*, 41(21):7204-8.

35. Freestone, D (2018) International Law and Sea Level Rise Sydney Conference 2018 Report. International Law Association: Sydney. Available from: https://ila.vettoreweb.com/Storage/Download.aspx?DbStorageId=11613&StorageFileGuid=ad6266c3-43c5-49d0-88b6-1ed11e59e772

36. Freestone D, Schofield C (2016) Current legal developments: Republic of the Marshall Islands. *The International Journal of Marine and Coastal Law*, 31(4):732-758.

37. Freestone D, Vidas D, Camprubi A. (2017) Sea level rise and impacts on maritime zone limits: the work of the ILA committee on international law and sea level rise. *Korean Journal of International and Comparative Law*, 4:1-36.

38. Gallo N, Allen DM, Victor D, Levin L (2017) Ocean Commitments under the Paris Agreement. *Nature Climate Change*, 7:833-840.

39. Golden CD, Allison EH, Cheung WW, Dey MM, Halpern BS, et al. (2016) Nutrition: Fall in fish catch threatens human health. *Nature*, 534:317–320.

40. Gössling S, Hall CM, Scott D (2009) 'The challenges of tourism as a development strategy in an era of global climate change', in Palosuo E (ed) Rethinking development in a carbon-constrained world: Development cooperation and climate change. Helsinki: Ministry for Foreign Affairs of Finland. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.468.5735&rep=rep1&type=pdf#page=102

41. Government of Tonga Ministry of Information and Communications (2015) Prime Minister Hon. Samuela 'Akilisi Pohiva signs the Taputapuātea Declaration on Climate Change in Tahiti (Press Release) [accessed 2018 Oct 9]. Available from: http://mic.gov.to/news-today/press-releases/5484-prime-minister-hon-samuela-akilisi-pohiva-signs-the-taputaputea-declaration-on-climate-change-in-tahiti

42. Harper S, Zeller D, Hauzer M, Pauly D, Sumaila UR (2013) Women and fisheries: Contribution to food security and local economies. *Marine Policy*, 39:56-63.

43. Holding S, Allen DM, Foster S, Hsieh A, Larocque I, Klassen J, et al (2016) Groundwater vulnerability on small islands. *Nature Climate Change*. 6:1100-1104.

44. IPCC (2018) Summary for Policymakers of the Special Report on Global Warming of 1.5°C (SR15). Incheon: IPCC.

45. Seidel H, Lal PN (2010) Economic value of the Pacific ocean to the Pacific island countries and territories. Gland, Switzerland: IUCN. Available from: https://cmsdata.iucn.org/downloads/economic_value_of_the_pacific_ocean_to_the_pacific_island_countries_and_territories_p.pdf

46. Jackson LP, Grinsted A, Jevrejeva S (2018) 21st Century Sea-Level Rise in Line with the Paris Accord. *Earth's Future*, 6(2):213-29.

47. Jackson LP, Jevrejeva S (2016) A probabilistic approach to 21st century regional sea-level projections using RCP and High-end scenarios. *Global and Planetary Change*, 146:179-89.

48. Johnson JE, Allain V, Bell J, Lehodey P, Nicol S, Senina I (2018) 'Effects of climate change on oceanic fisheries relevant to the Pacific islands', in Pacific Marine Climate Change Report Card: Science Review 2018, 177-188. Available from https://reliefweb.int/sites/reliefweb.int/files/resources/11_Oceanic_Fisheries.pdf

49. Kälin W (2012) From the Nansen principles to the Nansen initiative. *Forced Migration Review*, 41:48-49.

50. Keener V, Marra J, Finucane M, Spooner D, Smith M (eds) (2012) Climate change and Pacific islands: indicators and impacts: Report for the 2012 Pacific Islands Regional climate assessment. Washington, DC: Island Press.

51. Kumar L, Taylor S (2015) Exposure of coastal built assets in the South Pacific to climate risks. *Nature Climate Change*, 5:992-997.

52. Kuruppu N, Liverman D (2011) Mental preparation for climate adaptation: The role of cognition and culture in enhancing adaptive capacity of water management in Kiribati. *Global Environmental Change*, 21(2):657-669.

53. Lam VW, Cheung WW, Reygondeau G, Sumaila UR (2016) Projected change in global fisheries revenues under climate change. *Scientific Reports,* 6:32607.

54. Lallemant-Moe RH (2018) The Polynesian political awakening in response to climate change. *Interdisciplinary Perspectives on Equality and Diversity*, 4(1).

55. McAdam J. Historical cross-border relocations in the Pacific: lessons for planned relocations in the context of climate change. The Journal of Pacific History 2014 07/03;49(3):301-327.

56. McCubbin S, Smit B, Pearce T (2015) Where does climate fit? Vulnerability to climate change in the context of multiple stressors in Funafuti, Tuvalu. *Global Environmental Change*, 30:43-55.

57. McIver L, Kim R, Woodward A, Hales S, Spickett J, Katscherian D, et al. (2016) Health impacts of climate change in Pacific island countries: a regional assessment of vulnerabilities and adaptation priorities. *Environmental Health Perspectives*, 124(11):1707-1714.

58. Ministry of Finance and Economic Development, Ministry of Fisheries and Marine Resource Development (2016) Fishing license revenues in Kiribati: 2016 Report. Available from: http://www.mfed.gov.ki/sites/default/files/Fishing%20License%20Revenues%20in%20Kiribati%20Report%202016_0.pdf

59. Nansen Initiative (2015) Agenda for the protection of cross-border displaced persons in the context of disasters and climate change. Geneva: Nansen Initiative [accessed 2018 Aug 1]; Available from: https://nanseninitiative.org/wp-content/uploads/2015/02/PROTECTION-AGENDA-VOLUME-1.pdf

60. Natuzzi ES, Joshua C, Shortus M, Reubin R, Dalipanda T, Ferran K, et al. (2016) Defining population health vulnerability following an extreme weather event in an urban Pacific island environment: Honiara, Solomon Islands. *The American Journal of Tropical Medicine and Hygiene*, 95(2):307-314.

61. Nisbet MC (2009) Communicating Climate Change: Why Frames Matter for Public Engagement. *Environment: Science and Policy for Sustainable Development*, 51(2):12-23.

62. Pew Charitable Trusts (2016). Netting billions: a global valuation of tuna [accessed 2018 Aug 1]. Available from: https://www.pewtrusts.org/en/research-and-analysis/reports/2016/05/netting-billions-a-global-valuation-of-tuna

63. Republic of the Marshall Islands (2018) Tile Til Eo 2050 climate strategy: "lighting the way". Available from:

https://unfccc.int/sites/default/files/resource/180924%20rmi%202050%20climate%20strategy%20final_0.pdf

64. Signed by the leaders of French Polynesia, Niue, Cook Islands, Samoa, Tokelau, Tonga and Tuvalu. (2015) The Polynesian P.A.C.T.: The Taputapuātea Declaration on Climate Change. Available from: http://www.samoagovt.ws/wp-content/uploads/2015/07/The-Polynesian-P.A.C.T.pdf
65. Smith J, Tahani L, Bobogare A, Bugoro H, Otto F, Fafale G, et al. (2017) Malaria early warning tool: linking inter-annual climate and malaria variability in northern Guadalcanal, Solomon Islands. *Malaria Journal*, 16(1).
66. SPC (2017) Progress report on the implementation plan for the framework for action on energy security in the Pacific 2010–2020 for the period April 2011 to December 2015. Suva: SPC. Available from: http://prdrse4all.spc.int/sites/default/files/faesp_progress_report-ilovepdf-compressed.pdf
67. SPREP (n.d.) Pacific islands and sea-level rise. Available from: https://www.sprep.org/attachments/Publications/FactSheet/Oceans/pacific-islands-sea-level-rise.pdf
68. Storlazzi CD, Elias EP, Berkowitz P (2015) Many atolls may be uninhabitable within decades due to Climate Change. *Scientific Reports*, 5:14546.
69. Storlazzi CD, Gingerich SB, van Dongeren A, Cheriton OM, Swarzenski PW, Quataert E, et al (2018) Most atolls will be uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding. *Science Advances*, 4(4):eaap9741.
70. Taylor KE, Stouffer RJ, Meehl GA (2012) An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, 93(4):485-98.
71. The Division for Ocean Affairs and the Law of the Sea of the UN (2018) Deposit of charts. Available from: http://www.un.org/Depts/los/LEGISLATIONANDTREATIES/depositpublicity.htm
72. Tidd A, Blanchard JL, Kell L, Watson RA (2018) Predicting global tuna vulnerabilities with spatial, economic, biological and climatic considerations. *Scientific Reports*, 8:10572.
73. Townhill B, Buckley P, Hills J, Moore T, Goyet S, Awnesh S et al. (eds) (2018) Pacific Marine Climate Change Report Card 2018. Available from: https://www.sprep.org/attachments/Publications/CC/cefas-pacific-islands-report-card.pdf
74. UNDP, AOSIS (2017) Rising tides, rising capacity: supporting a sustainable future for small island developing states. New York: UNDP. Available from: http://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/rising-tides-rising-capacity-supporting-a-sustainable-future-for.html

75. UNESCAP (2016) Developing renewable energy in Pacific Small Island Developing States. MPFD Policy Briefs No 42. Available from: https://www.unescap.org/sites/default/files/MPFD%20Policy%20Brief%20No42-Jun16.pdf

76. UNICEF. Children and climate change: children's vulnerability to climate change and disaster impacts in East Asia and the Pacific. Bangkok: 2011. Available from: https://www.unicef.org/environment/files/Climate_Change_Regional_Report_14_Nov_final.pdf

77. UNICEF, United Nations in the Pacific: (2017) United Nations Pacific Strategy 2018-2022: a multi-country sustainable development framework in the Pacific region. Bangkok: UNICEF. Available from: https://www.unicef.org/about/execboard/files/Final_UNPS_2018-2022_Pacific.pdf

78. UN (2016) Sustainable Development Goals [accessed 2018 Aug 1]. Available from: https://sustainabledevelopment.un.org/?menu=1300

79. UN Women (2014) Climate change, gender and food security in the Pacific. Suva: UN Women. Available from: http://www2.unwomen.org/-/media/field%20office%20eseasia/docs/publications/2014/6/sids%20brief%205%20%20climate%20change%20gender%20and%20food%20security%20in%20the%20pacific.ashx?la=en

80. United Nations Development Programme (2017) Financing the SDGs in the Pacific Islands: opportunities, challenges and ways forward. New York: UNDP. Available from: http://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/financing-the-sdgs-in-the-pacific-islands--opportunities--challe.html

81. Victor DG (2017) Oceans on the front lines of global climate change. Washington, DC: Brookings Institution [accessed 2018 1 August]. Available from: https://www.brookings.edu/blog/planetpolicy/2017/10/31/oceans-on-the-front-lines-of-global-climate-change/.

82. Wahlen CB (2016) Parties Amend Montreal Protocol to Address HFCs [Press Release] (2016 Oct 17) [accessed 2018 Oct17]. Available from: http://sdg.iisd.org/news/parties-amend-montreal-protocol-to-address-hfcs/

83. Warren R, Price J, Graham E, Forstenhaeusler N, Van Der Wal J (2018) The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5° C rather than 2° C. *Science*, 360(6390):791-5.

84. Webber M, McDonald B (2004) Involuntary Resettlement, Production and Income: Evidence from Xiaolangdi, PRC. *World Development*, 32(4):673-690.

85. Whitmee S, Haines A, Beyrer C, Boltz F, Capon AG, de Souza Dias BF, et al. (2015) Safeguarding human health in the Anthropocene epoch: report of The Rockefeller

Foundation-Lancet Commission on planetary health. *The Lancet*, 386(10007):1973-2028.

86. World Health Organization (2015) Human Health and Climate Change in Pacific Island Countries. Manila: WHO. Available from: http://iris.wpro.who.int/bitstream/handle/10665.1/12399/9789290617303_eng.pdf?ua%20=1

87. World Health Organization (2011) Noncommunicable diseases country profiles 2011. Geneva: WHO. Available from: https://apps.who.int/iris/bitstream/handle/10665/44704/9789241502283_eng.pdf;jsessionid=D3DEBAA7481AD58E9116A63780AB550A?sequence=1

88. World Health Organization (2015) Operational Framework for Building Climate Resilient Health Systems. Geneva: WHO. Available from: https://apps.who.int/iris/bitstream/handle/10665/189951/9789241565073_eng.pdf;jses%20sionid=3CDBF3545B740C6380309BF3EBA5AD2E?sequence=1

89. World Health Organization (2010) Pacific Food Summit Fact Sheet [accessed 2018 Aug 1]. Available from: http://www.wpro.who.int/mediacentre/factsheets/fs14042010/en

90. World Health Organization (2016) Sanitation, drinking-water and health in Pacific island countries: 2015 update and future outlook. Manila: WHO. Available from: http://iris.wpro.who.int/bitstream/handle/10665.1/13130/9789290617471_eng.pdf

91. World Health Organization (2017). World Malaria Report 2017. Geneva: WHO. Available from: http://apps.who.int/iris/bitstream/handle/10665/259492/9789241565523-eng.pdf?sequence=1

92. Wolf F, Surroop D, Singh A, Leal W (2016) Energy access and security strategies in small island developing states. *Energy Policy*, 98:663-673.

93. World Bank (2013) Acting on climate change and disaster risk for the Pacific. Washington, DC: World Bank. Available from: http://www.worldbank.org/content/dam/Worldbank/document/EAP/Pacific%20Islands/climate-change-pacific.pdf

94. Cernea M, McDowell C (eds) (2000) Risks and reconstruction: experience of resettlers and refugees. Washington, DC: World Bank. Available from: http://documents.worldbank.org/curated/en/947311468739277702/pdf/multi-page.pdf

95. World Bank (2013) PCRAFI catastrophe risk assessment methodology. Washington, DC: World Bank. Available from: http://siteresources.worldbank.org/EXTDISASTER/Resources/8308420-1342531265657/PCRAFI_REPORT_WEB_Final.pdf.

96. World Bank (2015). PCRAFI country note: Samoa: disaster risk financing and insurance. Washington, DC: World Bank. Available from:

http://documents.worldbank.org/curated/en/443131468085732609/pdf/949840WP0Box03000Country0Note0Samoa.pdf.

97. World Bank (2018) PCRAFI Program Phase II: furthering disaster risk finance in the pacific. Washington, DC: World Bank. Available from: https://financialprotectionforum.org/publication/4-pager-pcrafi-program-furthering-disaster-risk-finance-in-the-pacific-2016-21

98. World Bank (2018) Tonga's cyclone Gita recovery receives significant boost [Press Release] (2018 Jun 15) [accessed 2018 Oct 1]; Available from: https://www.worldbank.org/en/news/press-release/2018/06/15/tongas-cyclone-gita-recovery-receives-significant-boost

99. World Bank (n.d.) Tourism: Pacific Possible. [accessed 2018 Aug 1]; Available from: http://pubdocs.worldbank.org/en/668071466580390790/PACIFIC-POSSIBLE-Tourism-Summary-paper.pdf

100. World Health Organization Representative Office in the South Pacific (2015) Noncommunicable diseases South Pacific situation summary [accessed 2018 Aug 1]; Available from: http://www.wpro.who.int/southpacific/programmes/healthy_communities/noncommunicable_diseases/page/en/

101. Wright S (1921) Correlation and causation. *Journal of Agricultural Research*, 20(7):557-585.

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