Chapter 15: Small Islands

Michelle Mycoo, Morgan Wairiu, Donovan Campbell, Virginie Duvat, Yimnang Golbuu, Shobha Maharaj, Johanna Nalau, Patrick Nunn, John Pinnegar, Olivia Warrick

Chapter 15: Small Islands

Coordinating Lead Authors: Michelle Mycoo (Trinidad and Tobago), Morgan Wairiu (Solomon Islands)

Lead Authors: Donovan Campbell (Jamaica), Virginie Duvat (France), Yimnang Golbuu (Palau), Shobha Maharaj (Germany/Trinidad and Tobago), Johanna Nalau (Australia/Finland), Patrick Nunn (Australia), John Pinnegar (United Kingdom), Olivia Warrick (New Zealand)

Contributing Authors: Giulia Anderson (USA/New Caledonia), Faye Abigail Cruz (Philippines), Eleanor Devenish-Nelson (United Kingdom), Kris Ebi (USA), Johanna Loehr (Germany), Roché Mahon (Trinidad and Tobago), Rebecca McNaught (Australia), Meg Parsons (New Zealand), Jeff Price (United Kingdom), Stacy-Ann Robinson (Jamaica), Adelle Thomas (Bahamas)

Review Editors: John Agard (Trinidad and Tobago), Mahmood Riyaz (Maldives)

Chapter Scientist: Giulia Anderson (USA/New Caledonia)

Date of Final Draft: 1 October 2021

Notes: TSU Compiled Version

Table of Contents

Executive Summary

Observed Impacts

A sense of urgency is prevalent among small islands in the combating of climate change and in adherence to the Paris Agreement to limit global warming to 1.5 °C above pre-industrial levels. Small islands are increasingly affected by increases in temperature, the growing impacts of tropical cyclones (TCs) , storm surges, droughts, changing precipitation patterns, sea-level rise (SLR), coral bleaching, and invasive species, all of which are already detectable across both natural and human systems (*very high confidence*[1]) {15.3.3.1, 15.3.3.2, 15.3.3.3, 15.3.4.1, 15.3.4.2, 15.3.4.3, 15.3.4.4, 15.3.4.5, 15.3.4.7}.

The observed impacts of climate change differ between urban and rural contexts, island types, and tropical and non-tropical islands (*high confidence*). Coastal cities and rural communities on small islands have been already impacted by sea-level rise, heavy precipitation events, tropical cyclones and storm surges. Climate change is also affecting settlements and infrastructure, health and wellbeing, water and food security, and economies and culture, especially through compound events (*high confidence*). As of 2017, an estimated 22 million people in the Caribbean live below 6 metres elevation and 50% of the Pacific's population lives within 10 km of the coast along with ≥50% of their infrastructure concentrated within 500 metres of the coast {15.3.4.1, 15.3.4.2, 15.3.4.3, 15.3.4.4, 15.3.4.5, 15.3.4.7}.

Tropical cyclones are severely impacting small islands (*high confidence*). The TC intensity and intensification rates at a global scale have increased in the past 40 years with intensity trends generally remaining positive. Intense TCs including categories 4 and 5 TCs have threatened human life and destroyed buildings and infrastructural assets in small islands in the Caribbean and the Pacific. Among 29 Caribbean islands, 22 were affected by at least one category 4 or 5 TC in 2017. TC Maria in 2017 destroyed nearly all of Dominica's infrastructure and losses amounted to over 225% of the annual GDP. Destruction from TC Winston in 2016 exceeded 20% of Fiji's current GDP. TC Pam devastated Vanuatu in 2015 and caused losses and damages to the agricultural sector valued at USD 56.5 million (64.1% of GDP). Coast-focused tourism is already extremely impacted by more intense TCs. {WGI 11.7.1, 12.4.7 15.2.1, 15.3.3.1, 15.3.3.3, 15.3.4.1, 15.3.4.2, 15,3.4.4, 15.3.4.5}.

Scientific evidence has confirmed that globally and in small islands tropical corals are presently at high risk (*high confidence*). Severe coral bleaching, together with declines in coral abundance have been observed in many small islands, especially those in the Pacific and Indian Oceans (*high confidence*). In the Pacific, median return time between two severe bleaching events has diminished steadily since 1980. The return time is now 6 years and often associated with the warm phase of ENSO events (*high confidence*). In Mid-2016, a new ENSO event occurred which reduced living coral cover by 75% in the Maldives {15.3.3.1.3, 15.3.4.8}.

Freshwater systems on small islands are exposed to dynamic climate impacts and are among the most threatened on the planet. An 11-36% reduction is estimated in the volume of fresh groundwater lens of the small atoll islands (area < 0.6 km^2) of the Maldives due to SLR. The El Niño related 2015-16 drought in Vanuatu led to reliance on small amounts of contaminated water left at the bottom of household tanks. A Caribbean high-resolution drought atlas spanning 1950–2016 indicates that the region-wide 2013–2016 drought was the most severe event during the multi-decadal period. In Puerto Rico, the island experienced 80 consecutive weeks of moderate drought, 48 weeks of severe drought and 33 weeks of extreme drought conditions between 2014 and 2016. Increasing trends in drought are apparent in the Caribbean although trends in the western Pacific are not statistically significant {15.3.3.2, 15.3.4.3}.

Small islands host significant levels of global terrestrial species diversity and endemism. Due to the large range of insular-related vulnerabilities, almost 50% of terrestrial species presently considered at risk of global extinction also occur on islands (*high confidence*)**.** Despite encompassing approximately two percent

[1] In this Report, the following summary terms are used to describe the available evidence: limited, medium, or robust; and for the degree of agreement: low, medium, or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high, and very high, and typeset in italics, e.g., *medium confidence*. For a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence.

of the Earth's terrestrial surface, oceanic and other high-endemicity islands are estimated to harbour substantial proportions of existing species including ~ 25% extant global flora, ~ 12% birds and ~10% mammals {15.3.3.3}.

Projected Impacts

Projected climate and ocean-related changes will significantly affect marine and terrestrial ecosystems and ecosystem services, which will in turn have cascading impacts across both natural and human systems (*high confidence*). Changes in wave climate superimposed on SLR will significantly increase coastal flooding (*high confidence*) and low-coastal and reef island erosion (*limited evidence, medium agreement*). The frequency, extent, duration, and consequences of coastal flooding will significantly increase from 2050 (*high confidence*), unless coastal and marine ecosystems are able to naturally adapt to SLR through vertical growth (*low confidence*). These changes are a major concern for small islands given that a high percentage of their population, infrastructure and economic assets are located in the low elevation coastal zone of below 10 metres elevation {15.3.3.1.1, 15.3.3.1.2, 15.3.3.1.3, 15.3.3.1.4}.

Projected changes in the wave climate superimposed on SLR will rapidly increase flooding in small islands, despite highly contrasting exposure profiles between ocean sub-regions (*high confidence*). A 5-10 cm additional SLR (expected for ~2030–2050) will double flooding frequency in much of the Indian Ocean and Tropical Pacific, while TCs will remain the main driver of (rarer) flooding in the Caribbean Sea and Southern Tropical Pacific. Some Pacific atoll islands will *likely*[2] undergo annual wave-driven flooding over their entire surface from the 2060s–2070s to 2090s under RCP8.5, although future reef growth may delay the onset of flooding (*limited evidence, low agreement*) {15.3.3.1.1}.

Modelling of both temperature and ocean acidification effects under future climate scenarios (RCP 4.5 and RCP 8.5) suggest that some small islands will experience severe coral bleaching on an annual basis before 2040 (*medium confidence*). Above 1.5°C, globally inclusive of small islands, it is projected there will be further loss of 70–90% of reef-building corals, with 99% of corals being lost under warming of 2°C or more above the pre-industrial period. Intact coral reefs, seagrass meadows and mangroves provide a variety of ecosystem services that are important to island communities (*high confidence*). These include provisioning services regulating services, cultural services and those that support community resilience (*high confidence)*. If coastal ecosystems are degraded and lost, then the benefits they provide cannot be easily replaced (*medium confidence*) {15.3.3.1.3, 15.3.3.1.4}.

Projected changes in aridity are expected to impose freshwater stress on many small islands, especially SIDS *(high confidence*). It is estimated that with a warming of 1.5°C or less, freshwater stress on small islands would be 25% less as compared to 2.0°C. While some island regions are projected to experience substantial freshwater decline, an opposite trend is observed for some western Pacific and northern Indian Ocean islands. Drought risk projections for Caribbean SIDS aligned with observations from the Shared Socio-Economic Pathway (SSP) 2 scenario, indicate that a 1°C increase in temperature (from 1.7°C to 2.7°C) could result in a 60% increase in the number of people projected to experience a severe water resources stress from 2043–2071. In some Pacific atolls, freshwater resources could be significantly affected by a 0.40 m SLR. Similar impacts are anticipated for some Caribbean countries with worst-case scenario (RCP8.5) indicating a 0.5-m SLR by the mid-century (2046-2065) and 1-m SLR by the end-of-century (2081-2100). In SIDS with high projected population growth rates, they are expected to experience the most severe freshwater stress by 2030 under a 2°C warming threshold scenario {15.3.3.2}

The continued degradation and transformation of terrestrial and marine ecosystems of small islands due to human-dominated will amplify the vulnerability of island peoples to the impacts of climate change (*high confidence*). New studies highlight large population reductions with an extinction risk of 100% for endemic species within insular biodiversity hotspots including within the Caribbean, Pacific and

[2] In this Report, the following terms have been used to indicate the assessed likelihood of an outcome or a result: Virtually certain 99–100% probability, Very likely 90–100%, Likely 66–100%, About as likely as not 33–66%, Unlikely 0–33%, Very unlikely 0–10%, and Exceptionally unlikely 0–1%. Additional terms (Extremely likely: 95–100%, More likely than not >50–100%, and Extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g., *very likely*). This Report also uses the term '*likely* range' to indicate that the assessed likelihood of an outcome lies within the 17-83% probability range.

Suandaland regions by 2100 for > 3°C warming {15.3.3.3}. This is *likely* to decrease the provision of resources (e.g. potable water) to the millions of people living on small islands, resulting in impacts upon settlements and infrastructure, food and water security, health, economies, culture, and migration (*high confidence*) {15.3.3.2, 15.3.3.3, 15.3.4.1, 15.3.4.2, 15.4.3, 15.3.4.4, 15.3.4.5, 15.3.4.6, 15.3.4.7}.

Reef island and coastal area habitability in small islands is expected to decrease because of increased temperature, extreme sea levels and degradation of buffering ecosystems, which will increase human exposure to sea-related hazards (*high confidence*). Climate and non-climate drivers of reduced habitability are context specific. On small islands, coastal land loss attributable to higher sea level, increased extreme precipitation and wave impacts, and increased aridity have contributed to food and water insecurities that are *likely* to become more acute in many places (*high confidence*). In the Caribbean, additional warming by 0.2°–1.0°C, could lead to a predominantly drier region (5%–15% less rain than present-day), a greater occurrence of droughts along with associated impacts on agricultural production and yield in the region. Crop suitability modelling on several commercially important crops grown in Jamaica found that even an increase less than + 1.5 °C could result in a reduction in the range of crops that farmers may grow. Most Pacific Island Countries could experience ≥ 50% declines in maximum fish catch potential by 2100 relative to 1980–2000 under both an RCP 2.6 and RCP 8.5 scenario {15.3.4.3, 15.3.4.4}.

Future Risks

The reduced habitability of small islands is an overarching significant risk caused by a combination of several Key Risks facing most small islands even under a global temperature scenario of 1.5 degrees *(high confidence)*. These are loss of marine and coastal biodiversity and ecosystem services; submergence of reef islands); loss of terrestrial biodiversity and ecosystem services ; water insecurity ; destruction of settlements and infrastructure ; degradation of health and well-being ; economic decline and livelihood failure); and loss of cultural resources and heritage. Climate-related ocean changes, including those for slow onset events, and changes in extreme events are projected to cause and/or amplify Keys Risks in most small islands. Identification of Key Risks facilitates the selection of optimal context-specific adaptation options. Moreover, it can distil the benefits and/or disadvantages and long-term implications of choosing such options (*high confidence*) {15.3.4.9}.

The vulnerability of communities in small islands, especially those relying on coral reef systems for livelihoods, may exceed adaptation limits well before 2100 even for a low greenhouse gas emission pathway (*high confidence*). The impacts of climate change on vulnerable low-lying and coastal areas, present serious threats to the ability of land to support human life and livelihood's (*high confidence*). Climate-related migration is expected to increase, although the drivers and outcomes are highly context-specific and insufficient evidence exists to estimate numbers of climate-related migrants now and in the future (*medium evidence, high agreement*) {15.3.4.1, 15.3.4.6, CCB7-1}.

Small islands are already reporting loss and damage particularly from tropical cyclones and increases in sea-level rise *(high confidence)*. Despite the loss of human life and economic damage the methods and mechanisms to assess climate-induced loss and damage remain largely undeveloped for small islands. Further, there are no robust methodologies to infer attribution and such assessments are limited. A research gap on loss and damage includes how to assess the economic costs of loss and damage. Specific data on experienced loss and damage across socio-economic groups and demographics are needed. Monitoring and tracking slow onset events are equally important and require robust data {15.7, 15.8}.

Options, Limits and Opportunities of Adaptation

Some island communities are resilient with strong social safety nets and social capital that support responses and actions already occurring, but there is limited information on the effectiveness of the adaptation practices and the scale of needed action (*high confidence*). This is in part due to a need for a better understanding of the limits to adaptation and of what constitutes current resilience and/or successful adaptation in small island contexts. Greater insights into which drivers weaken local and indigenous resilience, together with recognition of the socio-political contexts within which communities operate, and the processes by which decisions are made, can assist in identifying opportunities at all scales to enhance climate adaptation and enable action towards climate resilient development pathways (*medium evidence, high agreement*) {15.6.1, 15.6.5, 15.7}.

In small islands, despite the existence of adaptation barriers several enablers can be used to improve adaptation outcomes and to build resilience (*high confidence*). These enablers include better governance and legal reforms; improving justice, equity and gender considerations; building human resource capacity; increased finance and risk transfer mechanisms; education and awareness programmes; increased access to climate information; adequately downscaled climate data and embedding Indigenous Knowledge and Local Knowledge (IKLK) as well as integrating cultural resources into decision-making (*high confidence*) {15.6.1 15.6.3, 15.6.4, 15.6.5}.

Small islands present the most urgent need for investment in capacity building and adaptation strategies (*high confidence*) but face barriers and constraints which hinder the implementation of adaptation responses. Barriers and constraints arise from governance arrangements, financial resources and human resource capacity. Additionally, institutional and legal systems are often inadequately prepared for managing adaptation strategies such as large-scale settlement relocation and other planned and/or autonomous responses to climate risks (*high confidence*). Adaptation strategies are already being implemented on some small islands although barriers are encountered including inadequate up-to-date and locally relevant information, limited availability of finance and technology, lack of integration of IKLK in adaptation strategies, and institutional constraints (*high confidence*) {15.5.3, 15.5.4, 15.6.3, 15.6.4, 15.6.5}.

For many small islands, adaptation actions are often incremental and do not match the scale of extreme or compounding events (*high confidence*). Much of the currently implemented adaptation measures remain small in scale (e.g., community-based adaptation projects), sectoral in focus and do not address the needed structural and system level adaptations to combat climate impacts and achieve long term sustainability of adaptation interventions. To address these shortcomings enablers are being integrated into National Adaptation Plans and Disaster Risk Reduction Plans (*high confidence*) {15.6.3}.

Although international climate finance has increased in magnitude small islands face challenges in accessing adaptation finance to cope with slow and rapid onset events (*high confidence*). In the Caribbean, 38% of flows were concessional loans and 62% were grants whereas in the Atlantic and Indian Oceans nearly 75% of the flows were in the form of concessional loans and 25% were grants. Solutions to these barriers are being explored and some small islands have started adopting enablers such as insurance and microfinance at both the national and local levels in responding to adaptation needs and to facilitate resiliency building. COVID-19 has caused, however, economic shock in many small islands which will limit adaptation, undermine the attainment of Sustainable Development Goals and slow down climate resilient development transitions {15.8.3}.

The unavailability of up-to-date baseline data and contrasting scenarios/temperature levels continue to impair the generation of local-to-regional observed and projected impacts for small islands, especially those that are developing nations (*high agreement*). Climate model data based on the most recent suite of scenarios (RCPs and especially SSPs) are still not widely available to primary modelling communities in most small island developing nations (*high agreement*). Coastal sites of small islands are not well-represented in global gridded population and elevation datasets, thereby making estimation of population exposure to SLR difficult. The lack of data continues to impede the development of robust impacts-based modelling output (e.g. for terrestrial biodiversity). Downscaling is pivotal for small islands due to their high diversity which makes generalisation invalid.

15.1 Introduction

This chapter examines the climate change impacts and projected risks faced by small islands, including the detection and attribution of observed impacts, the loss and damage they experience, and the enablers, limits and barriers to the implementation of adaptation options applicable to them. The implications of climate change impacts on the attainment of the Sustainable Development Goals (SDGs), the need for more climate-resilient development pathways based on a systems transitions approach, and how both of these intersect with future potential responses are assessed within the context of small island states.

The small islands covered in this chapter are located within the tropics of the southern, northern, and western Pacific Ocean, the central, eastern and western Indian Ocean, the Caribbean Sea, the eastern Atlantic off the coast of West Africa, and in the temperate Mediterranean Sea. In contrast to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), non-sovereign island states and territories dependent on continental states and islands of semi-autonomous, sub-national island jurisdictions are included in this chapter. Further, Small Island Developing States (SIDS) consisting of 39 small island and low-lying coastal developing states which belong to the Alliance of Small Island States (AOSIS) are covered in this assessment. Islands in the polar and sub-polar regions, North Atlantic Ocean, the Baltic Sea, the North Sea, the Black Sea and the Arctic Ocean are not included.

Small islands share similarities such as geographical remoteness, isolation, narrow resource bases, heavy dependency on external trade, vulnerability to exogenous economic shocks, economic volatility, and limited access to development finance. Many are biodiversity hotspots and experience a disproportionate impact of natural hazards associated with climate change. They are also diverse in physical and biophysical characteristics, economic systems, political/governance systems, and exhibit social and cultural differences. Adaptation responses vary among small islands because such diversity requires place-specific and culturally-specific adaptation responses.

The chapter is structured in accordance with the overall format of the AR6 Working Group II report (Figure 15.1). This section presents points of departure from AR5 and IPCC (Section 15.2). As shown in Figure 15.1, this is followed by an assessment of current and future risks that are expected to be experienced by small islands (Sections 15.3 and 15.4), what measures have been implemented (Section 15.5) and enablers, limits and barriers that are being encountered (Section 15.6). Section 15.7 deals with the SDGs, climate-resilient development pathways and potential future responses. The chapter ends with an identification of research gaps (Section 15.8).

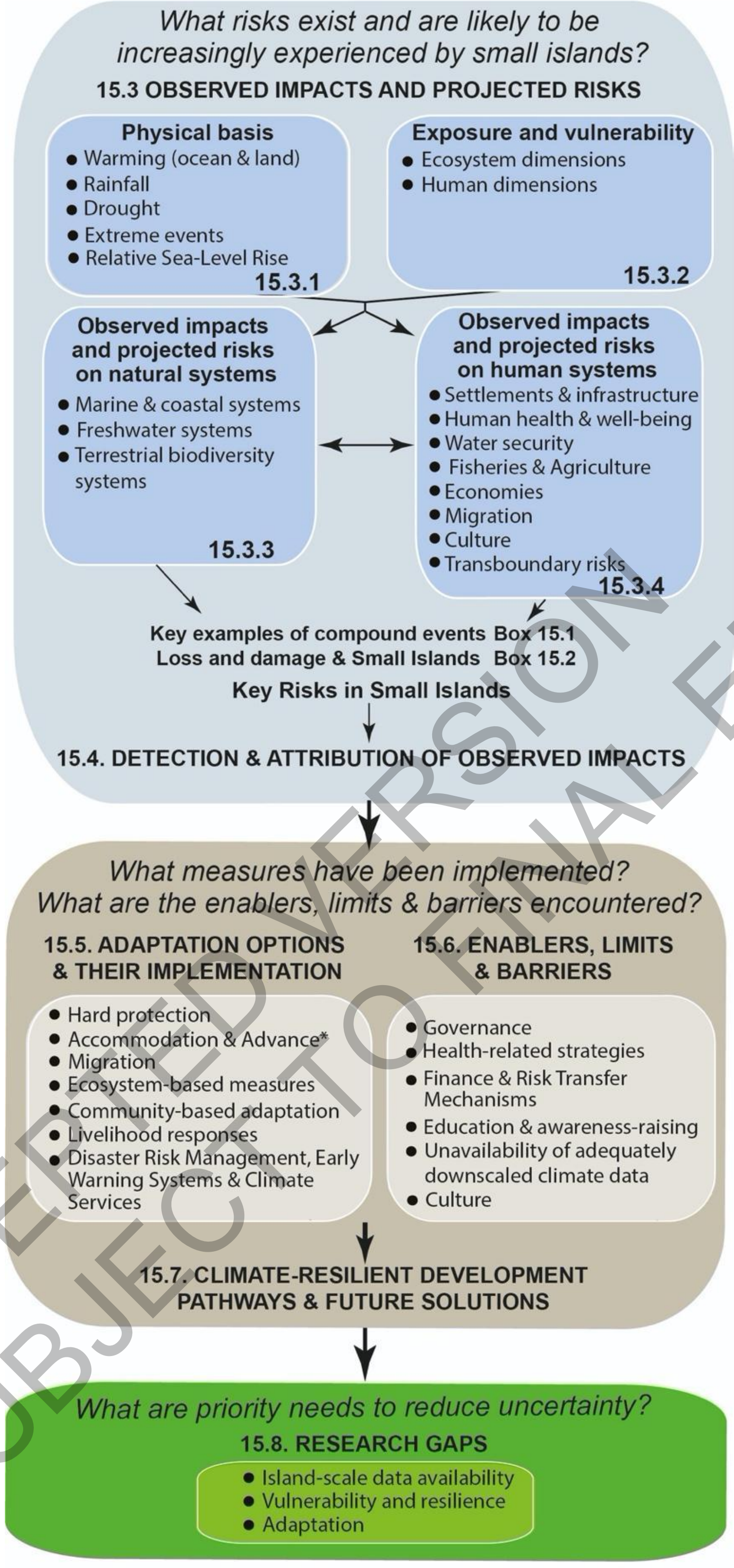


Figure 15.1: Schematic illustration of the interconnections of Chapter 15 themes, including on observed impacts and projected risks (Section 15.3) and on adaptation options and their implementation (Sections 15.5 and 15.6).

15.2 Points of Departure from AR5

Points of departure from AR5 are highlighted in this section in relation to exposure, vulnerability, impacts and risks (Section 15.2.1), and adaptation options (Section 15.2.2).

15.2.1 Points of Departure on Exposure, Vulnerability, Impacts and Risks

Scientific studies since AR5 confirm that global temperature will continue to increase even if greenhouse gas emissions are drastically reduced and will escalate the vulnerability, impacts and multiple interrelated risks experienced by small islands (*high confidence*) (IPCC, 2018). A greater sense of urgency in lowering global greenhouse gas emissions and a call for action now is resonating among small island states.

Post-AR5 new studies confirm observed impacts on the natural and human systems and indicate projected risks in both these systems over time. Over the past four decades, there was a significant increase in the probability of the global exceedances of tropical cyclones (TCs) of major intensity (Kossin et al., 2020), a trend confirmed by the occurrence of a growing number of intense TCs affecting the Atlantic and Pacific regions since AR5 (Magee et al., 2016; Bhatia et al., 2019; Knutson et al., 2019). Since AR5 also scientific evidence has confirmed that tropical corals are presently at high risk (*very high confidence*) and if global warming exceeds 1.5°C, known coral reef restoration options may be ineffective (IPCC, 2018). Even achieving emissions reduction targets consistent with the ambitious goal of 1.5°C of global warming under the Paris Agreement will result in the further loss of 70–90% of reef-building corals compared to today, with 99% of corals being lost under warming of 2°C or more above the pre-industrial period (*high confidence*) (Hoegh-Guldberg et al., 2018).

Additionally, since the last assessment more robust scientific evidence exists on the impacts of sea level rise (SLR) and extreme sea level events (ESL) on small islands. Under Representative Concentration Pathways emission scenarios, RCP2.6, RCP4.5 and RCP8.5, many low-lying coastal areas at all latitudes, including small islands, will experience SLR and ESL events such as coastal storm surges and coastal flooding more frequently in the coming decades (Section 4.2.3.4.1; IPCC, 2019). SLR and ESL events will affect atoll islands and islands with higher elevations differently. New studies forecast that small islands are *likely* to experience some of the largest increases in endemic extinctions and may substantially contribute to future global biodiversity loss, as well as to impaired ecosystem functioning (Fortini et al., 2015; Vogiatzakis et al., 2016; Cramer et al., 2018). Scientific evidence points to large population reductions with an extinction risk of 100% for endemic species within insular biodiversity hotspots by 2100 (IPBES, 2018; Manes et al., 2021). An overarching concern since AR5 is the reduced habitability of small islands. Eight key risks affecting the habitability of small islands are identified in this assessment and these are covered in the pertinent sections of this chapter which assess adaptation responses.

15.2.2 Points of Departure on Adaptation

New knowledge of adaptation responses used in small islands has grown significantly since AR5. Strategies include hard protection, land reclamation and permanent relocation, with improved appreciation for when each strategy is relevant (IPCC, 2019). Evidence of migration as an adaptation response to climate change remains limited (Roland and Curtis, 2020). Understanding of ecosystem-based adaptation (EbA) has improved considerably but there is *medium agreement* regarding its benefits (Doswald et al., 2014; Nalau et al., 2018a) and *limited evidence and low agreement* on its economic efficiency and long-term effectiveness (Renaud et al., 2016; Oppenheimer et al., 2019).

Since the previous assessment, integration of Indigenous Knowledge and Local Knowledge (IKLK) into adaptation is recognized as a major benefit in preparing and recovering from TCs and EbA (Narayan et al., 2020). The roles of social capital, health-related adaptation strategies and livelihood responses are more fully understood (Nalau et al., 2018b; Nunn and Kumar, 2018; Abram et al., 2019; IPCC, 2019). Gender equity, climate justice, climate services, early warning systems, and disaster risk reduction (Vaughan and Dessai, 2014; Newth and Gunasekera, 2018), which were data gaps in AR5, have received more treatment, especially in the context of small islands. Stronger evidence confirms that education and awareness-raising enhance household and community adaptation (*high confidence*).

Knowledge has improved on limits to adaptation, including projected timeframes of limits for hard protection (*high confidence*) and EbA (*medium confidence*) (IPCC, 2019). There is also a better understanding that barriers and governance challenges vary by island and island groups (*high confidence*) and result in them having different adaptive capacities (IPCC, 2019). A major barrier to adaptation is limited information on the feasibility, outcomes and sustainability of adaptation responses in small islands. Moreover, limited time series data on monitoring and evaluation make evaluating the feasibility of adaptation responses difficult.

Adaptation financing for small islands has increased since AR5 although leveraging finance is a constraint and remains complex (Robinson and Dornan, 2017). Informal microfinancing has grown and risk transfer mechanisms are being explored although funding and access to insurance schemes is limited (Handmer and Nalau, 2019; Nunn and Kumar, 2019a; Petzold and Magnan, 2019). In small islands the methods and mechanisms to assess climate-induced loss or damage remain undeveloped (*medium confidence*) (Thomas and Benjamin, 2017; Handmer and Nalau, 2019).

Many small islands have experienced economic shock arising from COVID-19 and have had to re-direct investment previously targeting sustainable development (Sheller, 2020). Adaptation will be affected by economic contraction and indebtedness. Framing adaptation within climate-resilient development pathways (CRDPs) that emphasise systems transition and are implemented at scale may bolster small islands' resilience to multiple shocks like COVID-19.

15.3 Observed Impacts and Projected Risks of Climate Change

Compared to larger landmasses, many climate change driven impacts and risks are amplified for small islands. This is due largely to their boundedness (surrounded by ocean), their comparatively small land areas, and often their remoteness from more populated parts of the world, which restricts the global connectivity of islands. This is true on all types of islands (Figure 15.2).

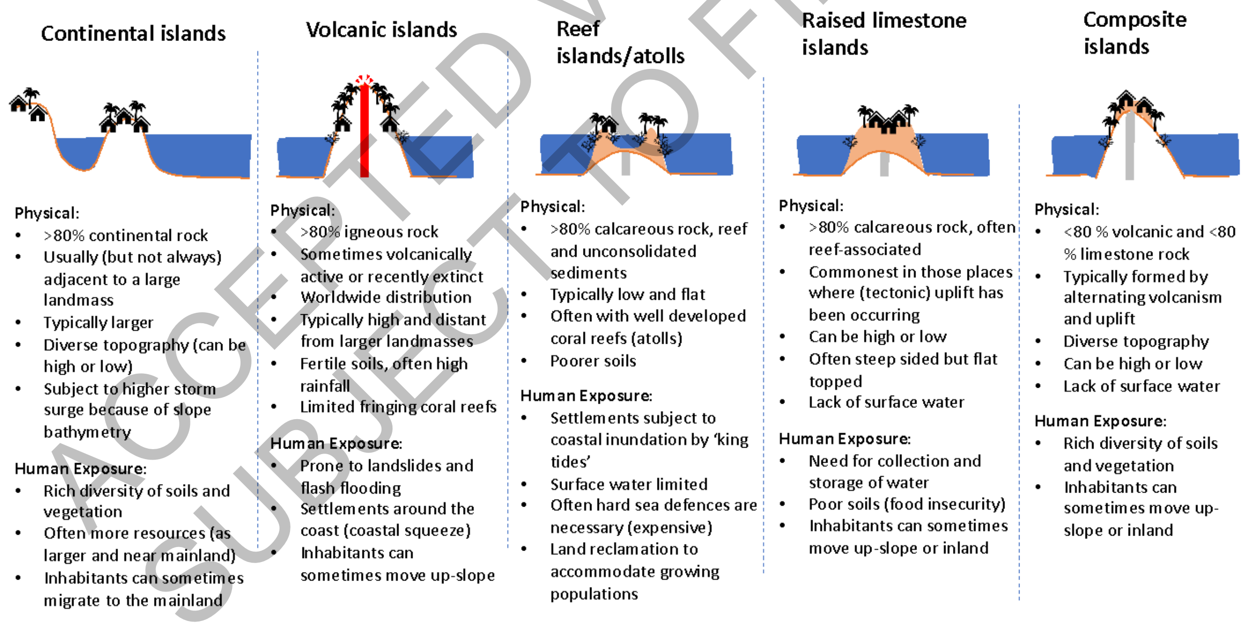


Figure 15.2: Classification of small island types - showing island characteristics and elements of human exposure (based on Nunn et al. (2016); Kumar et al. (2018)).

15.3.1 Synthesis of Observed and Projected Changes in the Physical Basis

There is increased evidence of warming in the small islands, particularly in the latter half of the 20th century (*high confidence*). The diversity of metrics and timescales used across studies makes it impossible to provide explicit comparisons, however Table 15.1 provides a summary of observed changes.

Table 15.1: Observed changes in basic climate metrics. RSLR: Relative Sea-Level Rise

Phenomenon	Location	Basic Trends	Specific Metric	Time period	Reference Literature
Air temp	West Pacific	Warmer	Increase in daily mean minimum temp by 0.14C/ decade	1951-2015	McGree et al. (2019)
Air temp	Caribbean	Warmer	Increase in daily minimum temp by 0.28C/ decade	1961-2010	Stephenson et al. (2014)
Air temp	Mediterranean	Warmer	Increase in annual mean surface temp 0.19-0.25C/ decade	1960-2005	Mariotti et al. (2015)
Land & Sea temp	Mediterranean	Warmer	Annual mean temperatures are now 1.54°C above the 1860-1890 level for land and sea		(MedECC, 2020)
Rainfall	Mediterranean	Drier	Decrease in annual mean precipitation by -0.6 mm/day/decade	1960-2005	Mariotti et al. (2015); Ducrocq et al. (2016)
Rainfall	Pacific Ocean	No clear pattern	No significant long-term trends in rainfall	1951-2015	McGree et al. (2019)
Rainfall	Indian Ocean	No clear pattern		1983-2015	Nguyen et al. (2018)
Rainfall	Caribbean	No clear pattern	No significant long-term trends in rainfall in the Caribbean over the 20th century	1901-2012	Jones et al. (2015)
Drought	Caribbean	Low confidence in the direction of change	Inconsistent between subregions and not statistically significant	1950-2016	Herrera and Ault (2017)
Drought	Pacific Ocean	Low confidence in the direction of change	Inconsistent between subregions and not statistically significant in the tropical Pacific. Significant decrease in Hawaii and sub-tropical South Pacific	1951-2015	McGree et al. (2016); McGree et al. (2019)
Tropical Cyclones	North Atlantic	Increase in intensity and decrease in frequency		1975-2009	Walsh et al. (2016)
Tropical Cyclones	Western North Pacific	Decreasing frequency	Decrease in frequency except over central North Pacific.	1977-2010	Walsh et al. (2016)
Tropical Cyclones	South Pacific	Increase in intensity and decrease in frequency		1989-2009	Walsh et al. (2016) Kuleshov et al. (2020)

Tropical Cyclones	Indian Ocean	No clear pattern	Poor data coverage	1961-2008	Tauvale and Tsuboki (2019); Kuleshov et al. (2020)
RSLR	East Caribbean	Greater than average	3-5mm/year	1993-2014	Becker et al. (2019)
RSLR	West/North Caribbean	Greater than average	2.5-3mm/year	1993-2014	Becker et al. (2019)
RSLR	Western Tropical Pacific	Greater than average	5-11mm/year	1993-2014	Becker et al. (2019)
RSLR	Mauritius/ Indian Ocean	Greater than average	4mm/year	1993-2014	Becker et al. (2019)
RSLR	Rodrigues/ Indian Ocean	Greater than average	6mm/year	1993-2014	Becker et al. (2019)

Some phenomena have no demonstrable trends in a region because of limited observed data, these include Tropical Cyclone (TC) frequency in the North-Eastern Pacific and Indian Oceans (Walsh et al., 2016); other phenomena are too variable to detect an overarching trend, including rainfall in regions where inter-annual and decadal variabilities such as the El Niño-Southern Oscillation, North Atlantic Oscillation, Pacific Decadal Variability, Atlantic Multidecadal Variability are dominant (Jones et al., 2015; McGree et al., 2019).

There are also marked regional variations in the rates of Sea Level Rise (SLR) (Merrifield and Maltrud, 2011; Palanisamy et al., 2012; Esteban et al., 2019) and Relative (that is, incorporating land movement) Sea-level Rise (RSLR). Various factors, including interannual and decadal sea level variations associated with low frequency modulation of ENSO and the Pacific Decadal Oscillation (PDO) and vertical land motion contribute to both relative sea-level variations and related uncertainties. Increased distant-source swell height from extra-tropical cyclones (ETCs) also contributes to Extreme Sea Levels (ESLs) (Mentaschi et al., 2017; Vitousek et al., 2017). Together, these stressors increase ESLs and their impacts, including coastal erosion and marine flooding and their impacts on both ecosystems and ecosystem services and human activities (Section 15.3.3.1 and Table 15.3).

Like observed impacts, projected impacts include some high confidence assessments, which are distributed across a diversity of models, timescales, and metrics. Generalised trends, and specific projections when available, are provided in Table 15.2. However, actual values and spatial distribution of precipitation changes remain uncertain as they are strongly model dependent (Paeth et al., 2017). Furthermore, the current capabilities of climate models, to adequately represent variability in climate drivers including ENSO, and the topography of small islands, limit confidence in these future changes (Cai et al., 2015a; Harter et al., 2015; Guilyardi et al., 2016).

Table 15.2: A small subset of projected changes in basic climate metric. Med=Mediterranean; NC=no change
[INSERT TABLE 15.2 HERE]

15.3.2 Trends in Exposure and Vulnerability

Most of the research that has been conducted on exposure and vulnerability from climate change demonstrates that factors including those that are geopolitical and political, environmental, socio-economic and cultural, together conspire to increase exposure and vulnerability of small islands (Box 15.1; Betzold, 2015; McCubbin et al., 2015; Duvat et al., 2017b; Otto et al., 2017; Weir et al., 2017; Taupo et al., 2018;

Barclay et al., 2019; Hay et al., 2019a; Ratter et al., 2019; Salmon et al., 2019; Bordner et al., 2020; Douglass and Cooper, 2020; Duvat et al., 2020a). Additional pressures on coastal and marine environments, including overexploitation of natural resources, may further exacerbate possible impacts in the future (Bell et al., 2013; Pinnegar et al., 2019; Siegel et al., 2019).

Furthermore, these factors exacerbate climate change induced problems such as coastal flooding and erosion faced by small islands. These impacts continue to worsen, which put small islands at increasingly higher risk to the impacts of climate change (Box 15.1). There are multiple stressors that affect the vulnerability of small islands to climate change (McNamara et al., 2019).

The problems of increasing exposure and vulnerability is most clearly seen in atoll islands. For example, in the capital of Tuvalu, economic stressors, food related stressors, and overcrowding make the islands much more vulnerable to climate impacts including changing precipitation patterns, ESLs, intense strong winds, warming SST and ocean acidification (McCubbin et al., 2015). Small islands, in trying to address the problem of limited land availability, put in place practices that lead to increasing exposure for island people. In Majuro, Marshall Islands (Ford, 2012), Tarawa, Kiribati (Biribo and Woodroffe, 2013; Duvat, 2013), and the Maldives Islands (Kench, 2012; Naylor, 2015; Duvat and Magnan, 2019b), population growth has led to land reclamation and the building of coastal protection structures, such as seawalls. Land reclamation and coastal protection structures negatively impact coastal and marine ecosystems, including reefs and mangroves, which compromise the protection services that they deliver to island communities through wave energy attenuation and sediment supply (Gracia et al., 2018; Curnick et al., 2019; Duvat and Magnan, 2019a) and may impact the long term sustainable adaptive planning of islands (Giardino et al., 2018). In addition, these construction activities disrupt natural coastal processes, thereby causing coastal erosion, which in turn increases the risk of flooding (Yamano et al., 2007; Duvat et al., 2017b) (Figure 15.3). This becomes a vicious cycle, with more land reclamation necessary to accommodate growing populations. Land reclamation requires stabilisation by protection structures, which then contributes to environmental degradation that increases the exposure and vulnerability of the communities living in these atolls (Duvat et al., 2017b).

Figure 15.3: Percentage of current population in selected small islands occupying vulnerable land (the number of people on land that may be exposed to coastal inundation—either by permanently falling below MHHW, or temporarily falling below the local annual flood height) in 2100 under an RCP4.5 scenario (adapted from Kulp and Strauss (2019) using the CoastalDEM_Perm_p50 model). Positions on the map are based on the capital city or largest town.

15.3.3 Observed Impacts and Projected Risks on Natural Systems

15.3.3.1 Impacts on Marine and Coastal Systems

15.3.3.1.1 Submergence and flooding of islands and coastal areas

Recent studies confirmed that observed ESL events causing extensive flooding generally resulted from compound effects, including the combination of SLR (Section 3.2.2.2 and Cross-Chapter Box SLR in Chapter 3) with ETCs, TCs and tropical depressions (WGI AR6 Sections 11.7.1 and 11.7.2), ENSO-related high-water levels associated with high or spring tide and/or local human disturbances amplifying impacts (*high confidence*). For example, the major floods that occurred in 1987 and 2007 in the Maldives involved the combination of distant-source swells and high spring tides and the settlement of reclaimed low-lying areas (Box 15.1; Wadey et al., 2017). In the Tuamotu atolls, French Polynesia, the 1996 and 2011 floods were due to the combination of distant-source swells causing lagoon filling and the obstruction of inter-islet channels by human-built structures (Canavesio, 2019). In 2011, the flooding of the lagoon-facing coast of Majuro Atoll, Marshall Islands, resulted from the combination of high sea levels occurring during La Niña conditions and seasonally high tides (Ford et al., 2018). Another example is the widespread flooding caused by distant TC Pam (2015) in Kiribati and Tuvalu, which was attributed to the strong swell generated, the long duration of the event and exceptionally high regional sea levels (Hoeke et al., 2021). On high tropical islands, major floods often occurred during TC events, due to the cumulative effects of storm surge and river flooding, the impacts of which were exacerbated by human-induced changes to natural processes in urban areas. This for example occurred in 2014 (TC Bejisa) in Reunion Island, France, in a harbour area favourable to water accumulation (Duvat et al., 2016); in 2015 (TC Pam) in Port Vila, Vanuatu, where urbanisation and human-induced changes to the river exacerbated flooding (Rey et al., 2017); and in 2017 (TC Irma) in Saint-Martin, Caribbean, where urbanisation had the same effect (Rey et al., 2019). Successive tropical depressions generating heavy rains were also involved in extensive flooding, for example in 2012 in Fiji (Kuleshov et al., 2014) and in 2014 in the Solomon Islands (Ha'apio et al., 2019).

Reconstructions of past storm surges and modelling studies assessing storm surge risk similarly highlighted high variations of risk along island coasts, due to variations in exposure, topography and bathymetry (*high confidence*). For example, the storm surge caused by TC Oli (2010) on the high volcanic island of Tubuai, French Polynesia, ranged from a few centimetres to 2.5 m, depending on coast exposure (Barriot et al., 2016). Investigating the contribution of reef characteristics to variations in wave-driven flooding on Roi-Namur Island, Kwajalein Atoll, Marshall Islands, (Quataert et al., 2015) found that the coasts fronted by narrow reefs with steep fore reef slopes and smoother reef flats are the most flood-prone. Modelling studies assessing storm surge risk in Fiji (McInnes et al., 2014) and Samoa (McInnes et al., 2016) confirmed the influence of coast exposure and water depth on risk distribution. In Apia, Samoa, Hoeke et al. (2015, p. 1117) found "differences in extreme sea levels in the order of 1 m at spatial scales of less than 1 km" and estimated (p. 1131) that a "1 m SLR relative to constant topography increases wave energy reaching the shore by up to 200% during storm surges." These studies reaffirmed the main control exerted by SLR on ESL events and associated storm surges compared to ENSO (*high confidence*). In Hawaii and the Caribbean, SLR is projected to exponentially increase flooding, with nearly every centimeter of SLR causing a doubling of the probability of flooding (Taherkhani et al., 2020). Simulations of SLR-induced flooding resulting from the combination of (i) direct marine flooding, (ii) flow reversal in drainage networks caused by extreme tide levels and (iii) the elevation of groundwater levels, at Honolulu, Hawaii, highlighted the major influence of this latter component (which is the most difficult to manage), as well as the increase of the proportion of triple-mechanism flooding as sea level rises (Habel et al., 2020). Where coral reefs buffer flooding through wave attenuation, flooding will be further aggravated by reef decline over time (Section 15.3.3.1.3).

Larger-scale studies confirmed that projected changes in the wave climate superimposed on SLR will rapidly increase flooding in small islands, despite highly contrasting exposure profiles between ocean sub-regions (*high confidence*) (Shope et al., 2016; Mentaschi et al., 2017; Shope et al., 2017; Vitousek et al., 2017; Morim et al., 2019). In particular, Vitousek et al. (2017) showed that even a 5-10 cm additional SLR (expected for ~2030–2050) will double flooding frequency in much of the Indian Ocean and Tropical Pacific, while TCs will remain the main driver of (rarer) flooding in the Caribbean Sea and Southern Tropical Pacific (Figure 15.3). Some Pacific atoll islands, which already experience major floods, will *likely* undergo annual wave-driven flooding over their entire surface from the 2060s–2070s (Storlazzi et al., 2018) to 2090s (Beetham et al., 2017) under RCP8.5, although future reef growth may delay the onset of flooding (*limited evidence, low agreement*) (Key Risk KR2 in Figure 15.5).

15.3.3.1.2 Reef island destabilisation and coastal erosion

Over the past three to five decades, shoreline changes were dominated by stability on reef islands and erosion on high islands; attribution of observed erosion to SLR and other climate change-related drivers is challenged by the complex interplay of multiple climatic, ecological and human drivers (*high confidence*). Since the 1950s-1970s, and even in regions exhibiting higher than global averaged SLR rates, atoll islands maintained their land area (*high confidence).* A literature review including 709 Indian and Pacific Oceans atoll islands showed that 73.1% of these islands were stable in area, while respectively 15.5% and 11.4% increased and decreased in area (Duvat, 2018). The rates of change did not correlate with SLR rates, suggesting that the impact of SLR on island land area was obscured by other climate drivers and human disturbances on some islands (*high confidence*) (Kench et al., 2015; McLean and Kench, 2015; Duvat, 2018). However, reef island disappearance and reduction in land area was clearly observed in New Caledonia and the Solomon Islands, and was attributed to the synergistic interactions of gradual SLR with stronger trade winds causing higher sea levels and local tectonics in the Solomon Islands (Albert et al., 2016; Garcin et al., 2016). Despite important knowledge gaps on coastal erosion in high tropical islands, recent studies confirmed increasing shoreline retreat and beach loss over the past decades, mainly due to TC and ETC waves and human disturbances (*high confidence*) (e.g., in the Caribbean region: Anguilla, Saint-Kitts, Nevis, Montserrat, Dominica and Grenada (Cambers, 2009; Reguero et al., 2018)), and Pacific (Hawaii (Romine and Fletcher, 2013); Tubuai, French Polynesia (Salmon et al., 2019)) and Indian Oceans (Anjouan, Comoros (Ratter et al., 2016)).

Despite storm-induced erosion prevailing along some shoreline sections, recent studies reaffirmed the contribution of TC and ETC waves to coastal and reef island vertical building through massive reef-to-island sediment transfer *(high confidence*). For example, TC Ophelia (1958) and Category 5 TC Fantala (2016), which respectively eroded the islands of Jaluit Atoll, Marshall Islands (Ford and Kench, 2016), and Farquhar Atoll, Seychelles (Duvat et al., 2017c), also contributed to island and beach expansion. Likewise, tropical depressions can have constructional effects, as reported on Fakarava Atoll, French Polynesia (Duvat et al., 2020b). On Saint-Martin/Sint Maarten and Saint-Barthélemy, the 2017 hurricanes, which caused marked shoreline retreat at most beach sites, also allowed beach formation and beach ridge development along some natural coasts (Duvat et al., 2019a; Pillet et al., 2019). Similarly, El Niño and La Niña were involved in rapid and highly contrasting shoreline changes (*high confidence*), including reef island accretion in the Ryukyu Islands, Japan (Kayanne et al., 2016), beach shifts on Maiana and Aranuka Atolls, Kiribati (Rankey, 2011), and beach erosion on Hawaii, USA (Barnard et al., 2015). These contrasting shoreline responses were respectively due to coral reef degradation from past bleaching events providing material to islands, wave directional shifts, and increased wave energy. The role of bleaching events in increasing short-term sediment generation in atoll contexts was confirmed by a study conducted on Gaafu Dhaalu Atoll, Maldives, which reported an increase of sediment production from ~0.5 kg CaCO3 m–2 yr^{-1} to ~3.7 kg CaCO3 m-2 yr^{-1} between 2016 (pre-bleaching) and 2019 (bleaching + 3 years) (Perry et al., 2020).

There is *high confidence* that accelerating SLR and increased wave height will affect the geomorphology of reef islands (Baldock et al., 2015; Costa et al., 2019; Tuck et al., 2019) and coastal systems on high islands (Grady et al., 2013; Barnard et al., 2015; Bindoff et al., 2019), and that the responses of these systems will highly depend on changes in boundary conditions (wave regime and direction, exposure to extreme events, impacts of ocean warming and acidification on supporting ecosystems, bathymetry and reef flat roughness) and the degree of disturbance of their natural dynamics by human activities (Smithers and Hoeke, 2014; McLean and Kench, 2015; Bheeroo et al., 2016; Ratter et al., 2016; Shope et al., 2016; Duvat et al., 2017a; Kench and Mann, 2017; Kench et al., 2018; Duvat et al., 2019a). Reef islands and beach and beach-dune systems that are not disturbed by human activities are respectively expected to migrate lagoonward (Webb and Kench, 2010; Albert et al., 2016; Beetham et al., 2017; Costa et al., 2019; Tuck et al., 2019) and landward (Bindoff et al., 2019), and to also experience increased erosion as well as changes in configuration, volume and elevation (Kench and Mann, 2017; Tuck et al., 2019) (Bramante et al., 2020; Kane and Fletcher, 2020). Small reef islands and narrow coastal systems affected by human disturbances will increasingly be at risk of disappearance due to SLR (KR2 in Figure 15.5), enhanced sediment loss caused by extreme events (Duvat et al., 2019a) and/or human activities (*high confidence*), as reported in Hawaii (Romine and Fletcher, 2013), Puerto Rico (Jackson et al., 2012), Sicily (Anfuso et al., 2012), and Takuu, Papua New Guinea (Mann and Westphal, 2014). SLR will also increase coastal erosion in the Mediterranean Sea, (e.g., in the Aegean Archipelago, Greece (Monioudi et al., 2017)), and Mallorca, Spain (Enríquez et al., 2017).

15.3.3.1.3 Impacts on marine and coastal ecosystems

Loss of marine and coastal biodiversity and ecosystem services is a Key Risk in small islands (see KR1 in Figure 15.5). Coral bleaching caused by elevated water temperatures is the most visible and widespread manifestation of a climate change impact on coastal ecosystems in most small islands but is far from being the only one (Section 3.4.2.1; Section 5.3.4; Spalding and Brown, 2015; Hoegh-Guldberg et al., 2017; IPCC, 2018; Bindoff et al., 2019; Sully et al., 2019). Severe coral bleaching, together with declines in coral abundance have been documented in many small islands, especially those in the Pacific and Indian Oceans,(e.g., Guam, Fiji, Palau, Vanuatu, Chagos, Comoros, Mauritius, Seychelles, and the Maldives (*high confidence*) (Box 15.1; Golbuu et al., 2007; Woesik et al., 2012; Perry and Morgan, 2017; Hughes et al., 2018). During severe bleaching events, not only do reefs lose a significant amount of live coral cover, but they also experience a decrease in growth potential, so reef erosion surpasses reef accretion (Perry and Morgan, 2017). Median return time between two severe bleaching events has diminished steadily since 1980 and is now only 6 years (e.g.,Hughes et al., 2017b; Hughes et al., 2018) and is often associated with warm phase of ENSO events (*high confidence*) (Lix et al., 2016). Modelling of both bleaching and ocean acidification effects under future climate scenarios suggested that some Pacific small islands (e.g., Nauru, Guam, Northern Marianas Islands) will experience conditions that cause severe bleaching on an annual basis before 2040 and that 90% of the world reefs are projected to experience conditions that result in severe bleaching annually by 2055 (*medium confidence*) (van Hooidonk et al., 2016). Models are currently predicting the large-scale loss of coral reefs by mid-century under even low-emissions scenarios. Even achieving emissions reduction targets consistent with the ambitious goal of 1.5°C of global warming under the Paris Agreement will result in the further loss of 70–90% of reef-building corals compared to today, with 99% of corals being lost under warming of 2°C or more above the pre-industrial period (*high confidence*) (Hoegh-Guldberg et al., 2018).

Satellite data and local field studies at 3351 sites in 81 countries including small islands show that not all coral reefs are equally exposed to severe temperature stress events, and even similar coral reefs exposed to similar conditions show local and regional variation and species-specific responses (Sully et al., 2019). There is great variability in terms of sensitivity of corals to climate change, as also demonstrated in the Comoros Archipelago (Cowburn et al., 2018), in the Pacific (Fox et al., 2019; Mollica et al., 2019; Romero-Torres et al., 2020) and globally (Sully et al., 2019; McClanahan et al., 2020). It has been hypothesised that low-latitude tropical reefs bleached less than those in higher latitudes because: (i) of the geographical differences in species composition, (ii) of the higher genotypic diversity at low latitudes, and (iii) some corals were pre-adapted to thermal stress because of consistently warmer temperatures at low latitude prior to thermal stress events (Sully et al., 2019). However, latitudinal variation was not reported in other global surveys of coral bleaching occurrence (Donner et al., 2017; Hughes et al., 2017a; Hughes et al., 2017b; McClanahan et al., 2019). Ainsworth et al. (2016) and Ateweberhan et al. (2013) showed that coral bleaching can be mitigated by pre-exposure to elevated temperatures. Regionally, recovery is also highly variable. While some reefs in the Seychelles and Maldives were shown to recover to pre-disturbance levels of coral cover after previous bleaching events (Box 15.1; Pisapia et al., 2016; Koester et al., 2020), other reefs underwent seemingly permanent regime shifts toward domination by fleshy macro algae (Graham et al., 2015), or major declines in carbonate budgets, and thus the capacity of reefs to sustain vertical growth under rising sea levels (Perry and Morgan, 2017).

Despite their vital social and ecological value, substantial declines in seagrass communities have been documented in many small islands (Section 3.4.2.5; Arias-Ortiz et al., 2018; Kendrick et al., 2019; Brodie et al., 2020), including Fiji (Joseph et al., 2019), Reunion Island (Cuvillier et al., 2017), Bermuda, Cayman Islands, US Virgin Islands (Waycott et al., 2009), Kiribati (Brodie et al., 2020), Federated States of Micronesia, and Palau (Short et al., 2016), but attribution of such declines to climatic influences remains weak (*low confidence*). Impact of climate change on seagrasses goes beyond the loss of seagrass but includes acceleration of seagrass decomposition (Kelaher et al., 2018), palatability (Jimenez-Ramos et al., 2017) and the cumulative effect of warming and eutrophication (Ontoria et al., 2019). Seagrasses face a multitude of threats including physical disturbance and direct damage caused by rapidly growing human populations, declines in water quality, and coastal erosion (Short et al., 2016). Experimental studies have shown increased mortality, leaf necrosis, and respiration when seagrasses are exposed to higher-than-normal temperatures (Hernan et al., 2017). As such, seagrass meadows growing near the edge of their thermal tolerance are at risk from rising temperatures (Pedersen et al., 2016). In the Mediterranean, seagrass meadows are already showing signs of regression, which may have been aggravated by climate change (*high confidence*). Some studies suggest seagrasses have potential for acclimation and adaptation (Duarte et al., 2018; Ruiz et al., 2018; Beca-Carretero et al., 2020). Chefaoui et al. (2018) attempted to forecast the distribution of two seagrasses in the future, including around the islands of Cyprus, Malta, Sicily and the Balearic Islands. Under the worst-case scenario, *Posidonia oceanica* was projected to lose 75% of suitable habitat by 2050. Conversely, it has been suggested that seagrasses could actually benefit from an increase in anthropogenic carbon dioxide because of increased growth and photosynthesis (Hopley et al., 2007; Waycott et al., 2011; Sunday et al., 2016; Repolho et al., 2017). However, Collier et al. (2017) argued that when faced with increased heat waves, thermal stress will rarely be offset by the benefit of elevated CO2 and therefore that the widespread belief that seagrasses will be a 'winner' under future climate change conditions seems unlikely *(low confidence*).

Since 2011, the Caribbean region has been experiencing unprecedented influxes of the pelagic seaweed *Sargassum*. These extraordinary sargassum 'blooms' have resulted in mass strandings of sargassum throughout the Lesser Antilles, with significant damage to coastal habitats, mortality of seagrass beds and associated corals (van Tussenbroek et al., 2017), as well as consequences for fisheries and tourism. Whether or not such events are related to long-term climate change remains unclear, however it has been suggested that the influx may be related to strong Amazon discharge, enhanced West African upwelling, together with rising seawater temperatures in the Atlantic (*low confidence*) (Oviatt et al., 2019; Wang et al., 2019). Since 2011, the Pacific atoll nation of Tuvalu has also been affected by algal blooms, the most recent being a large growth of *Sargassum* on the main atoll of Funafuti, and this phenomenon has been related to anthropogenic eutrophication and high seawater temperatures (De Ramon N'Yeurt and Iese, 2014).

Mangroves face serious risks from deforestation and unsustainable coastal development (Section 3.4.2.5; Gattuso et al., 2015). Large-scale die-offs around many small islands suggest that mangrove face increased risks from climate change (Sippo et al., 2018). Mangrove seaward edge retreat has been demonstrated in American Samoa and at Tikina Wai in Fiji, in Bermuda, West Papua, Grand Cayman and attributed to long-term SLR or tectonic subsidence (Ellison, 1993; Ellison, 2005; Gilman et al., 2007; Ellison and Strickland, 2015). Inundation-related mortality of mangroves could, in theory, be mitigated if mangrove substrates can "keep up" with rising sea level by accretion. Pacific Island studies using radionuclides (e.g., 210Pb, 137Cs) have suggested that most mangroves are keeping up with current rates of sea level rise (Alongi, 2008; MacKenzie et al., 2016), while surface elevation tables SETs suggest otherwise. Lovelock et al. (2015) reported that nearly 70% of the mangroves monitored with SETs are not keeping up with current SLR rates. If SLR exceeds 6 mm/yr, mangroves may be unable to maintain their elevation relative to sea level, a threshold likely to be surpassed in the next 30 years under high emission scenarios (Ellison, 1993; Saintilan et al., 2020). In these worst-case scenarios, flooding would result in tree, root, and rhizome death and an abrupt change in elevation through peat collapse (Krauss et al., 2010; Lang'at et al., 2014), creating a positive feedback loop between SLR and elevation loss. Geomorphology, hydrology, tidal range, and suspended sediments are important factors that will determine if mangroves will survive increased rates of SLR (Lovelock et al., 2015; Sasmito et al., 2015; Rogers et al., 2019). TCs can cause extensive damage to mangroves (Short et al., 2016). While immediate physical damage is often considerable, trees can sometimes recover by re-foliating, re-sprouting or regenerating (Kauffman and Cole, 2010). Examples of substantive mangrove recovery include the regrowth of trees in the Bay Islands of Honduras following Hurricane Mitch (October 1998) (Fickert, 2018) and in the Nicobar Islands, India, following the December 2004 Indian Ocean Tsunami (Nehru and Balasubramanian, 2018).

Sandy beaches are an important ecosystem in small islands, with high socio-economic as well as ecosystem services value (Ellison, 2018). Turtles and many seabirds nest just above the high-water mark on sandy beaches or among sand dunes, but TCs, rising seas, storm surges and heavy rainfall as well as inappropriate coastal development can erode beaches (Section 15.3.1.2) resulting in damage to nests and eggs (Fuentes et al., 2011). Beach-nesting turtle populations are projected to become threatened around many small islands as a result of future climate change (e.g., Bonaire - Netherlands Antilles (Fish et al., 2005), Bioko Island - Equatorial Guinea (Veelenturf et al., 2020), Cyprus (Varela et al., 2019), Raine Island – Australia (Pike et al., 2015)), although other populations such as those around the Cape Verde Islands are projected to remain relatively robust (Abella Perez et al., 2016). Turtles are also threatened by temperature rise around some small islands as warmer temperatures on nesting beaches can lead to an unbalanced sex-ratio in the population (e.g. St. Eustatius island, (Laloë et al., 2016)).

15.3.3.1.4 Marine and coastal ecosystem services

Intact coral reefs (Woodhead et al., 2019), seagrass meadows (Hejnowicz et al., 2015), and mangroves (UNEP, 2014b) (Friess, 2016) provide a variety of ecosystem services that are key to island communities, including provisioning services (e.g., timber, fisheries, aquaculture), regulating services (e.g., coastal protection, carbon storage, filtering of pollutants), cultural services (Pascua et al., 2017) as well as supporting community resilience (Förster et al., 2019). If coastal ecosystems are degraded and lost, then the benefits they provide are also lost (Oleson et al., 2018; Förster et al., 2019; Brodie et al., 2020). In small islands where the risk of loss to ecosystem services is high (Cross-Chapter Box DEEP in Chapter 17), many of these ecosystem services cannot be easily replaced (*medium confidence*). The beneficial role that coral reefs play in coastal protection through wave attenuation, and therefore enhancing climate resilience in small islands, has been extensively studied (e.g., Elliff and Silva, 2017; Harris et al., 2018; Reguero et al., 2018). Indeed, it has been demonstrated that in small islands (such as the Cayman Islands, Grenada, Bahamas) averted damages as a result of protecting intact coral reefs, can be considerable when expressed as a percentage of GDP (Beck et al., 2018). Ferrario et al. (2014) conducted a global meta-analysis including many small islands across the Atlantic, Pacific and Indian Oceans and found that coral reefs reduce wave height by an average of 84% (and wave energy by 97%) and that reef crests alone dissipate most of this energy. Based on another meta-analysis of 69 case studies worldwide (wave heights measured before and after the habitat), Narayan et al. (2016) observed that coral reefs, mangroves, and seagrass reduced wave height by 70%, 31% and 36%, respectively (Figure 15.4) and thus perform an essential role in protecting human lives and livelihoods (*high confidence*). Post-TC studies have provided additional evidence for the protection services offered by coastal ecosystems. On some Caribbean islands (e.g., Saint-Martin/Sint Maarten) where the dense indigenous vegetation belt was preserved, the vegetative structure buffered the waves of TCs Irma and José (2017), reducing the extent of marine inundation and shoreline retreat to a 30 m-wide coastal strip against values >160 m in deforested areas (Duvat et al., 2019a; Pillet et al., 2019). By contrast, the destruction of mangrove ecosystems, even a few trees around the fringes, can accelerate coastal erosion, as exemplified by observations in Micronesia (Krauss et al., 2010; Nunn et al., 2017a).

As corals, mangroves and seagrasses disappear, so do fish and other dependent organisms that directly benefit industries such as ecotourism and fisheries (*high confidence*) (Graham et al., 2015; Cinner et al., 2016). These impacts are sometimes exacerbated by catastrophic events such as tropical storms and marine heatwaves that destroy habitats and hence the resources upon which coastal fisheries depend (Sainsbury et al., 2018). There is *high confidence* that climate change impacts, together with local human disturbances, will continue to denude coastal and marine ecosystem services in many small islands with serious consequences for vulnerable communities (Elliff and Silva, 2017; Bindoff et al., 2019).

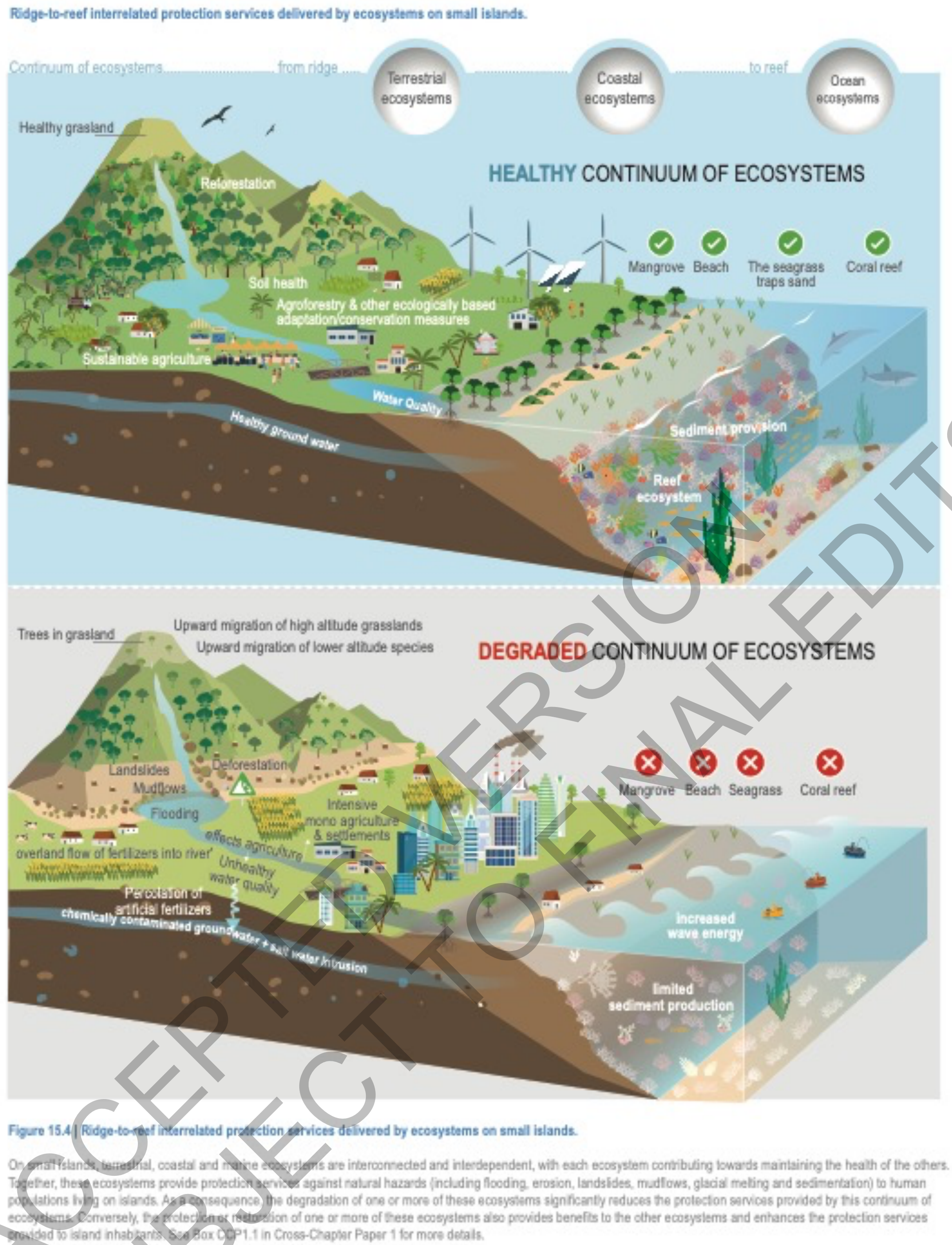


Figure 15.4: Ridge-to-reef interrelated protection services delivered by ecosystems on small islands. On small islands, terrestrial, coastal and marine ecosystems are interconnected and interdependent, with each ecosystem contributing towards maintaining the health of the others. Together, these ecosystems provide protection services against natural hazards (including flooding, erosion, landslides, mudflows, glacial melting and sedimentation) to human populations living on islands. As a consequence, the degradation of one or more of these ecosystems significantly reduces the protection services provided by this continuum of ecosystems. Conversely, the protection or restoration of one or more of these ecosystems also provides benefits to the other ecosystems and enhances the protection services provided to island inhabitants. See Box CCP1.1 for more details.

15.3.3.2 Impacts on Freshwater Systems

Freshwater systems on small islands are exposed to dynamic climate impacts and are considered to be among the most threatened on the planet (Key Risk 3 in Box 15.1; Settele et al., 2014; IPCC, 2018; Butchart et al., 2019). Hoegh-Guldberg et al. (2019) estimated that freshwater stress on small islands would be 25%

less with a warming of 1.5°C or less as compared to 2.0°C. While some island regions are projected to experience substantial freshwater decline, an opposite trend is observed for some western Pacific and northern Indian Ocean islands (Holding et al., 2016; Karnauskas et al., 2016). Island topography and ecophysiology influence water storage capacity and rainfall response potential (Dunn et al., 2018). On high volcanic and granitic islands, freshwater ecosystems are often closely connected with coastal spaces, and changes in freshwater supply from river systems have direct implications for salinity and sediment loads (*high confidence*) (Yang et al., 2015; Zahid et al., 2018). Climate impacts on streamflow patterns in tropical islands also create shifts in water supply for downstream users and habitat conditions for organisms supporting a wide range of ecosystem services (*high confidence*) (Strauch et al., 2015; Frazier and Brewington, 2019; Frauendorf et al., 2020).

Projected changes in aridity are expected to impose freshwater stress on many small islands, especially SIDS *(high confidence*).These changes are congruent with drought risk projections for Caribbean SIDS (Lehner et al., 2017; Taylor et al., 2018) and aligned with observations from the Shared Socio-Economic Pathway (SSP) 2 scenario, where a 1°C increase in temperature (from 1.7°C to 2.7°C) could result in a 60% increase in the number of people projected to experience a severe water resources stress from 2043–2071 (Schewe et al., 2014; Karnauskas et al., 2018). In the Mediterranean region, freshwater resources will decline 10–30% *(medium confidence)* (Koutroulis et al., 2016; Kumar et al., 2020). For example, analysis of annual and seasonal streamflow data on the island of Mallorca shows a decreasing trend during spring and summer, with a reduction of up to 17% in some basins (Garcia, 2017).

The influence of climate change spans several variables for atoll islands with multiple, interacting forces that exacerbate impacts on freshwater ecosystems (Connell, 2016), including groundwater and freshwater resources (Warix et al., 2017). Analysis of groundwater resources on Roi-Namur, in the Marshall Islands, reveals that the extent of salinisation of fresh groundwater lenses varies with the scale of the overwash (Gingerich et al., 2017). Alsumaiei and Bailey (2018) estimated an 11-36% reduction in the fresh groundwater lens volume of the small atoll islands (area < 0.6 km²) of the Maldives due to SLR. Small overwash events lead to saline conditions that last for up to 3 months (Oberle et al., 2017).

SLR undermines the long-term persistence of freshwater-dependent ecosystems on islands (Goodman et al., 2012) and is one of the greatest threats to the goods and services these environments provide (Box 16.1; Mitsch and Hernandez, 2013). Hoegh-Guldberg et al. (2019) posit that as sea level rises, managing the risk of salinisation of freshwater resources will become increasingly important. On Roi-Namur, Marshall Islands, Storlazzi et al. (2018) found that the availability of freshwater is impacted by the compounding effect of SLR and coastal flooding. In other Pacific atolls, Terry and Chui (2012) showed that freshwater resources could be significantly affected by a 0.40 m SLR. Similar impacts are anticipated for some Caribbean countries (Stennett-Brown et al., 2017). Such changes in SLR could increase salinity in estuarine and aquifer water, affecting ground and surface water resources for drinking and irrigation water (Mycoo, 2018a) across the region (*high confidence*). SLR also affects groundwater quality (Bailey et al., 2016), salinity (Gingerich et al., 2017), and water-table height (Masterson et al., 2014).

15.3.3.3 Impacts on Terrestrial Biodiversity Systems

Despite encompassing approximately two percent of the Earth's terrestrial surface, oceanic and other high-endemicity islands are estimated to harbour substantial proportions of existing species including ~ 25% extant global flora, ~ 12% birds and ~10% mammals (Alcover et al., 1998; Wetzel et al., 2013; Kumar and Tehrany, 2017). Islands also have higher densities of critically endangered species, hosting just under half of all species currently considered to be at risk of extinction (Spatz et al., 2017a; Spatz et al., 2017b), hence making the loss of terrestrial biodiversity and related ecosystem services a Key Risk (KR3) for small islands (Figure 15.5). Impacts from developing synergies between changing climate, natural and anthropogenic stressors on islands (Cross-Chapter Box DEEP in Chapter 17) could lead to disproportionate changes in global biodiversity. The most prominent drivers include: SLR, increasing intensities of extreme events (human activities — especially continuing/accelerating habitat destruction/degradation) and the introduction of invasive alien species (IAS) (Tershy et al., 2015). When coupled with characteristic small island traits such as spatial and other resource limitations, these synergies play a critical role towards increasing the vulnerability of these insular ecosystems (Box CCP1.1). This is likely to hinder the adaptation response of terrestrial biota ─ increasing the risk of biodiversity loss and in turn, impairing the resilience capacity of ecosystem functioning and services (*high confidence*) (Heller and Zavaleta, 2009; Ferreira et al., 2016; Vogiatzakis et al., 2016).

Current observations of insular species response to climate change generally report geographic range shifts/reductions for species and vegetation associations in addition to resulting impacts on local ecology (Virah-Sawmy et al., 2016; Koide et al., 2017; Maharaj et al., 2019). These include changes in plant/animal phenology and resulting community alterations such as for the common Mediterranean island species *Quercus ilex* (holly oak) and *Ficus carica* (common fig). Species have been shifting greater distances to access not only suitable climate conditions but also by association, suitable breeding conditions and seasonal food. Examples include: migratory birds such as *Coturnix coturnix* now having earlier spring arrival dates in the Mediterranean compared to six decades ago and the increased mortality of the iconic *Argyroxyphium sandwicense* (Hinahina) as result of warmer drier trends at Hawaiian high altitudes (Krushelnycky et al., 2012; Taylor and Kumar, 2016a; Vogiatzakis et al., 2016). There have also been die-offs of some species from temperature extremes (e.g., flying fox species: *Pteropus* species) within the Pacific islands (Taylor and Kumar, 2016a).

Recorded alterations of ecological interactions include increased competition, changes to migratory routes (Harter et al., 2015) and mismatches between species, such as increased pathogen attacks on Mediterranean forest species (Vogiatzakis et al., 2016). Also, in some areas of Madagascar there has been increased vulnerability to fire, due to the replacement of succulents by less fire resilient species (Virah-Sawmy et al., 2016). Further, the low functional redundancy of island ecosystems implies a comparatively higher proportion of keystone species than continents, many of them being endemics (Harter et al., 2015), with potentially unpredictable system consequences due to climate-induced ecological changes. For example, Caribbean land crabs have been observed to alter their food intake as a response to drying conditions (McGaw et al., 2019) and Aldabra giant land tortoises have reduced their activity in response to increasing temperature and decreasing precipitation (Falcon and Hansen, 2018); such changes in both these ecosystem engineers are of potential consequence for seed dispersal, among other ecological functions.

The majority of studies modelling geographical range changes of small island species, to even the most optimistic 21st century climate change scenarios imply a reduction in climate refugia (Table 15.3, Box CCP1.1). This is due to projected strong shifts, reductions or even complete losses of climatic niches resulting from inadequate geographic space for species to track suitable climate envelopes (*high confidence*) (e.g., Maharaj and New, 2013; Fortini et al., 2015; Struebig et al., 2015b). Because of the high proportion of global endemics hosted within small and especially isolated islands, the resulting increased extinction risk of such species (up to 100%) could lead to disproportionate losses in global biodiversity (m*edium to high confidence*) (Harter et al., 2015; Manes et al., 2021).

SLR has been projected to impact the terrestrial biodiversity of low-lying islands and coastal regions via large habitat losses both directly (e.g., submergence) and indirectly (e.g., salinity intrusion, salinisation of coastal wetlands and soil erosion) at even the 1m scenario (*medium to high confidence*). However, these impacts vary depending on the islands' topographical differences. In a study of SLR impacts on insular biodiversity hotspots, (Bellard et al., 2013a) reported that the Caribbean islands, Sundaland and the Philippines were projected to suffer the most habitat loss while the East Melanesian islands were projected to be lesser (but not minimally) affected. The most threatened of these, the Caribbean, was projected to have between 8.7% to 49.2% of its islands entirely submerged respectively from 1m to 6 m SLR (Bellard et al., 2013a). However, many current projection studies consider marine flooding directly and seldom incorporate other indirect impacts such as increased habitat losses from horizontal erosion loss, increased salinity levels, tidal ranges and extreme events. These projections are considered to be conservative, underestimating the extent of habitat loss to terrestrial biodiversity (Bellard et al., 2013b).

Marine flooding is expected to destroy habitats of coastal species, particularly range-restricted coastal and/or single-island endemics (many already listed as *at least* 'threatened' by the International Union for Conservation of Nature [IUCN]) within the limited terrain on atoll islands. These species have limited opportunities to accommodate such direct impacts of climate change apart from shifting further inland or to other neighbouring atolls which might have favourable habitat. However, fragmentation of habitat due to anthropogenic activity may hinder migration further inland, while shifting to neighbouring islands is not viable due to the water barrier between islands (*high confidence*) (Bellard et al., 2013b; Wetzel et al., 2013;

Kumar and Tehrany, 2017). Additionally, migratory birds, which use small islands (e.g. atolls) for stopovers or breeding/nesting sites, are projected to become impacted. Within the Mediterranean and Caribbean, significant losses to coastal wetlands - critical habitat for migratory birds has already been observed, with further significant habitat losses, redistribution and changes in quality being projected across island systems such as the Bahamas (Caribbean) and Sardinia (Mediterranean) (Vogiatzakis et al., 2016; Wolcott et al., 2018).

Indirect impacts of SLR may potentially result in equal or more biodiversity loss than direct impacts (*medium confidence*). Relocation of displaced coastal human populations and associated intensive agriculture and urban areas inland to natural habitat may result in greater biodiversity loss than direct impacts – especially on islands with large coastal populations and urban centres (Wetzel et al., 2012; Bellard et al., 2013b). Given the dense population of insular hotspots (~31.8% of existing humans within ~ 15.9% of inhabited global land area) and the fact that on many islands, large proportions of human populations live within coastal regions, it has been suggested that immense impacts from such relocations should be factored into projection and adaptation studies (Wetzel et al., 2012).

Tropical island natural habitats/systems are highly vulnerable to extreme weather events such as TCs, due to their small size, unique ecological systems and often low socio-economic capacity (*high confidence*) (Box 15.2; Goulding et al., 2016; Schütte et al., 2018). Growing evidence suggests high resilience of forest habitats (Keppel et al., 2014; Luke et al., 2017), especially within intact forest ecosystems to hurricanes and cyclones (Goulding et al., 2016). While initial damage can be high, relatively fast recovery rates have been reported for both floral and faunal components of these ecosystems (Cantrell et al., 2014; Shiels et al., 2014; Monoy et al., 2016; Richardson et al., 2018). Within the Caribbean in particular, high resilience of forest types has been associated with the *current* intensity and return rate of hurricanes over the last 150 years.

It should however be underscored that these relatively fast recovery rates are associated with the *present* intensity and return rate of TCs. They do not reflect the impacts of increasingly intense events such as Hurricane Dorian (2019), which resulted in almost complete inundation of several low-lying islands of the Bahamas from storm surges. Severe weather events also have indirect effects on islands' biodiversity — interacting synergistically with other stressors, such as increased invasion by non-native species and land use change. For example, TCs within Papua New Guinea resulted in the destruction of subsistence gardens, which led inhabitants to clear forest areas for new farming areas and for harvesting of timber resources to rebuild (Goulding et al., 2016).

The most recent projections suggest that TC intensity is predicted to increase as climate continues to change (Walsh et al., 2016; Kossin et al., 2017). There are too few studies available to suggest potential future response trends of these ecosystems to this increased intensity, however it seems plausible that present resilience capacities may be adversely impacted (*medium confidence*) (Marler, 2014). Further, the potential for stressors such as forest fragmentation/degradation or IAS combining with these increasingly intense events to cause precipitating ecosystem cascades is a real concern (Goulding et al., 2016).
Continued high rates of habitat loss and degradation have been reported for many small islands as natural habitats continue to be cleared to meet increasing demands upon natural resources from rising human populations, agriculture, urbanisation, unsustainable tourism, overgrazing and fires. This increases the vulnerability of ecosystems within especially oceanic islands — where isolation has given rise to high levels of endemism but simple biotic communities, with low functional redundancy (Box CCP1.1). There is *high confidence* that climate change may exacerbate the effects of this habitat loss upon the biodiversity of these islands as the climate refugia (Table 15.3) and the upslope shifts of range-restricted, dispersal-limited and poorly competitive species, confined within narrow latitudinal (and decreasing altitudinal) gradients, are increasingly challenged by fragmented and degraded landscapes (e.g., Struebig et al., 2015a; IPBES, 2019). Additionally, high-altitude ecosystems such as cloud forests which harbour high levels of endemism are projected to shrink due to increasing atmospheric temperature and competition from upward-shifting lowland species (Taylor and Kumar, 2016a). These may ultimately increase the risk of multiple extinctions, negatively impacting upon global biodiversity levels (*high confidence*) (Taylor and Kumar, 2016a; Portner et al., 2021).

Analyses of historical and current threats indicate that IAS and disease have been the primary drivers of insular extinctions in modern history (Bellard et al., 2016). Impacts of IAS on islands are projected to increase with time due to synergies between climate change and other traditional drivers such as increasing global trade, tourism, agricultural intensification, over exploitation and urbanisation (Bellard et al., 2014; Russell et al., 2017). Changing climate conditions may not necessarily increase the rate of IAS introductions but is expected to improve chances of IAS establishment via (i) altering IAS transport and introduction mechanisms, (ii) increasing the impacts and distributions of existing IAS and (iii) altering the effectiveness of existing control strategies (Hellmann et al., 2008; Russell et al., 2017). These are likely to enhance IAS impacts on islands including: restructuring of ecological communities leading to declines and extinctions/extirpations in flora and fauna, habitat degradation, declining ecosystem functioning, services and resilience, and in extreme cases, potential community homogenisation (*high confidence*) (Russell and Blackburn, 2017; IPBES, 2019). Given the high degree of endemicity within oceanic islands and their associated vulnerabilities, such exacerbation by changing climate pose a serious threat to decreasing global biodiversity (*medium to high confidence*) (van Kleunen et al., 2015).

Compared to continents, terrestrial IAS are disproportionately prevalent on islands (almost three-quarters of global species currently threatened by IAS and disease are found on islands) and also generate stronger impacts (e.g., within alpine ecosystems of high islands) than on continents (*high confidence)*(Bellard et al., 2014; Bellard et al., 2016; Frazier and Brewington, 2019). Russell and Blackburn (2017) suggested a correlation between small island size and increased numbers of IAS. SIDS within the Indian Ocean and in particular, the Pacific SIDS region were reported to have significantly more IAS (*medium confidence*), while the Caribbean and Atlantic SIDS have fewer numbers but faster accumulation of IAS. Finally, while there have been developments in the eradication of IAS on islands (Jones et al., 2016), there is sparse evidence and hence assessment of the degree to which measures designed to prevent introduction and to manage invasion pathways and establishment have been successful.

Table 15.3: Percentage of selected islands classified as refugia for biodiversity at increasing levels of warming. While protected land is still 'protected' this table demonstrates the difficulty of protecting lands which might be 'more resilient' to climate change under increasing levels of warming and current land use practices. Derived from current and future projected distributions of ~130,000 terrestrial fungi, plants, invertebrates and vertebrates (Warren et al., 2018a). Refugia =areas remaining climatically suitable for >75% of the species modelled (Warren et al., 2018b). **Projections:** based on mean impacts from 21 CMIP5 climate model patterns (no dispersal) and elevationally downscaled to 1km under interpolated warming levels derived from RCP 2.6, 4.5, 6.0 and 8.0 (Warren et al., 2018a). First column-set = % island/island chain classified as a refugia based on ***climate alone*** ; second column-set = % natural land projected to be climate refugia — illustrating potential refugia 'space' already lost to habitat conversion. **Colour Key**: white > 50%; yellow = 30%-50%; red = 17%-30% and dark red <17% of land classified as refugia.

[INSERT TABLE 15.3 HERE]

15.3.4 Observed Impacts and Projected Risks on Human Systems

15.3.4.1 Island Settlements and Infrastructure

As a result of slow onset ocean and climate changes and changes in extreme events, settlements and infrastructure of small islands are at growing risk due to climate change in the absence of adaptation measures (*high confidence*). Ocean acidification and deoxygenation, increased ocean temperatures and relative sea level rise are impacting marine, coastal and terrestrial biodiversity and ecosystem services, making settlements more exposed and vulnerable to climate-related hazards. Changes in rainfall patterns such as heavy precipitation result in annual flood events that damage major assets and result in a loss of human life. Examples of settlements where this has occurred are Port of Spain (Mycoo, 2014b; Mycoo, 2018a) , Haiti (Weissenberger, 2018), Viti Levu (Brown et al., 2017; Singh-Peterson and Iranacolaivalu, 2018), urban areas of Fiji and Kiribati (McAneney et al., 2017; Cauchi et al., 2021), Male', Maldives (Wadey et al., 2017), and Mahé, in the Seychelles (Etongo, 2019).

The main settlements of small islands are located along the coast and with decades of high density coastal urban development, their population, buildings and infrastructure are currently exposed to multiple climate change-related hazards (Kumar and Taylor, 2015; Mycoo, 2017) and face key risks (*high confidence*) (KR5 in Figure 15.5). In many small islands, population is concentrated in the Low Elevation Coastal Zone (LECZ) which is defined as coastal areas below 10 metres elevation. Approximately 22 million in the

Caribbean live below 6 metres elevation (Cashman and Nagdee, 2017) and an estimated 90% of Pacific Islanders live within 5 km of the coast, if Papua New Guinea is excluded (Andrew et al., 2019). In the Solomon Islands and Vanuatu, over 60% of the population lives within 1 km of the coast (Andrew et al., 2019). Most Pacific islands have ≥50% of their infrastructure within 500 metres of the coast (Kumar and Taylor, 2015), and in Kiribati, Marshall Islands and Tuvalu, >95% of the infrastructure is located in the LECZ (Andrew et al., 2019) (Figure 15.3). Sustainable development challenges including insufficient land use planning and land use competition contribute to increased vulnerability of human settlements to climate change in small islands (Kelman, 2014)(Mycoo, 2021).

Categories 4 and 5 TCs are severely impacting settlements and infrastructure in small islands. TC Maria in 2017 destroyed nearly all of Dominica's infrastructure and losses per unit of GDP amounted to more than 225% of the annual GDP (Eckstein et al., 2018). Destruction from TC Winston in 2016 amounted to more than 20% of Fiji's current GDP (Cox et al., 2018). Additionally, living conditions in human settlements are changing due to storm surge which is already penetrating further inland compared with a few decades ago (IPCC, 2018 Section 3.4.4.3; Brown et al., 2018).

A growing percentage of the population in small islands lives in informal settlements which occupy marginal lands leading to increased population exposure and vulnerability to climate-related hazards (Mycoo and Donovan, 2017). Unplanned settlements have compounded flooding brought on by slow onset hazards such as coastal and riverine flooding and fast onset events such as TCs and storm surges (Butcher-Gollach, 2015; Chandra and Gaganis, 2016; Mycoo, 2017). Unsustainable land use practices and difficulties in enforcing land use zoning and building guidelines in informal settlements make them highly vulnerable to such events (Butcher-Gollach, 2015; Mecartney and Connell, 2017; Mycoo, 2017; Mycoo, 2018b; Trundle et al., 2018; Mycoo, 2021).

TC intensification in the future is *likely* to cause severe damage to human settlements and infrastructure in small islands. Additionally, SLR is expected to cause significant loss and damage (Martyr-Koller et al., 2021). Based on SLR projections, almost all port and harbour facilities in the Caribbean will suffer inundation in the future (Cashman and Nagdee, 2017). In Jamaica and St Lucia, SLR and ESLs are projected to be key risks to transport infrastructure at 1.5°C unless further adaptation is undertaken (Monioudi et al., 2018). Similar findings were reported for Samoa (Fakhruddin et al., 2015). Even islands of higher elevation are expected to be threatened, given the high amount of infrastructure located near to the coast, for example Fiji (Kumar and Taylor, 2015).

15.3.4.2 Human Health and Well-being

Small islands face disproportionate health risks associated with changes in temperature and precipitation, climate variability, and extremes (Cross-Chapter Box INTERREG in Chapter 16; Key Risk 4 in Section 15.3.9, Figure 15.5). Climate change is projected to increase the current burden of climate-related health risks (Weatherdon et al., 2016; Ebi et al., 2018; Schnitter et al., 2019). Health risks can arise from exposures to extreme weather and climate events, including heatwaves; changes in ecological systems associated with changing weather patterns that can result, for example, in more disease vectors, or in compromised safety and security of water and food; and exposures related to disruption of health systems, migration, and other factors (see Cross-Chapter Box ILLNESS in Chapter 2; McIver et al., 2016; Mycoo, 2018a; WHO, 2018).

Extreme weather and climate events, particularly TCs, floods, drought, and heat waves can cause injuries, infectious diseases, and deaths (Box 15.1; Schütte et al., 2018). For example, category 5 TC Winston hit Fiji on 20 February 2016. During the national state of emergency (7 March and 29 May 2016), the World Health Organization portable toolkit for an early warning alert and response system (EWARS in a Box) was deployed within 24 hours; it recorded 34,113 cases of the nine syndromes among 326,861 consultations in a population of about 900,000; 48% of cases were influenza-like illnesses, 30% were acute watery diarrhoea, and 13% were suspected cases of dengue. There also were 583 cases of Zika-like illness (1.7% of all cases) and two large outbreaks of viral conjunctivitis (total of 880 cases). During TC Maria in Puerto Rico, there were more deaths per 100,000 among individuals living in municipalities with the lowest socioeconomic development and for men 65 years of age or older (Santos-Burgoa et al., 2018); this excess risk persisted for at least a year after the event. The first human cases of leptospirosis in the U.S. Virgin Islands occurred in

2017 after TC Irma and Maria. TCs also can affect treatment and care for people with non-communicable diseases, including exacerbation or complications of illness and premature death (Ryan et al., 2015).

Heat-related mortality and risks of occupational heat stress in small island states are projected to increase with higher temperatures (Hoegh-Guldberg et al., 2018; Mendez-Lazaro et al., 2018). Higher temperatures also can affect the productivity of outdoor workers (Taylor et al., 2021). Climate change, urbanization, and air pollution are risk factors for the rise of allergic diseases in Asia and the (Pawankar et al., 2020).

Tropical and sub-tropical islands face risks from vector-borne diseases, such as malaria, dengue fever, and the Zika virus. El Niño events can increase the risk of diseases such as Zika virus by increasing biting rates, decreasing mosquito mortality rates, and shortening the time required for the virus to replicate within the mosquito (Caminade et al., 2017). By combining disease prediction models with climate indicators that are routinely monitored, alongside evaluation tools it is possible to generate probabilistic dengue outlooks in the Caribbean and early warning systems (Oritz et al., 2015; Lowe et al., 2018). Projections suggest that more individuals will become at risk of dengue fever by the 2030s and beyond because of an increasing abundance of mosquitos and larger geographic range (Ebi et al., 2018). Projected increases in mean temperature could double the dengue burden in New Caledonia by 2100 (Teurlai et al., 2015). In the Caribbean, Saharan dust transported across the Atlantic can interact with Caribbean seasonal climatic conditions to become respirable and contribute to asthma presentations at the emergency department (See Table 15.5; Akpinar-Elci et al., 2015).

Ciguatera fish poisoning (CFP) is a foodborne illness caused by toxic dinoflagellate algae that proliferate on degraded coral reefs and that can contaminate reef fish; symptoms can remain for a few weeks to months. CFP occurs in tropical and subtropical regions, primarily in the South Pacific and Caribbean, but wherever reef fish are consumed (Traylor and Singhal, 2020). In the Caribbean Sea, increasing ocean temperatures are expected to stabilize or slightly decrease the incidence of CFP because of shifts in species distribution of dinoflagellates associated with CFP (Kibler et al., 2015). CFP is endemic in the Cook Islands and French Polynesia, where incidence is associated with sea surface temperature anomalies (Zheng et al., 2020). In the Canary Islands, tropicalization trends due to climate change are expected to increase CFP occurrence in the future (Rodriguez et al., 2017). In addition, in the Caribbean, increased density of *Sargassum* algae, possibly due to ocean temperature impacts on ocean currents compounded by agricultural pollution, may lead to increased respiratory illnesses (Resiere et al., 2018; Resiere et al., 2019; Resiere et al., 2020).

Climate driven changes in the ability to access locally grown or harvested food, either through environmental degradation or changes in extreme event magnitude and/or frequency, can increase dependence on imported food and increase rates of malnutrition and non-communicable diseases (Springmann et al., 2016; WHO, 2018; Savage et al., 2019; Lieber et al., 2020). Projections suggest that local food accessibility could be reduced by 3.2% in the low- and middle-income countries of the Western Pacific (including the Philippines, Fiji, Papua New Guinea, Solomon Islands, and other Pacific islands) by 2050, with approximately 300,000 associated deaths possible (Springmann et al., 2016). A climate change-related 20% decline in coral reef fish production in some Pacific Island countries by 2050 could exacerbate the population growth-driven gap between volume of fish needed for nutritional security and fish available through sustained harvest (Bell et al., 2013; Cauchi et al., 2019; Savage et al., 2019)).

Heavy reliance on aquifers and rainwater harvesting in small islands, particularly atolls, coupled with overcrowding, population growth, and contamination increase the risk of waterborne disease (McIver et al., 2014; Strauch et al., 2014; McIver et al., 2016). For example, seasonal rainfall in Kiribati is associated with waterborne disease (such as diarrhea, cholera, and typhoid fever). Future projections indicate increases in the number of days of heavy rainfall by 2050, suggesting future increases in risk in heavily populated areas (McIver et al., 2014). Damage to water and sanitation services can cause infectious disease outbreaks, such as the cholera outbreak that occurred in Haiti following TC Matthew (Raila and Anderson, 2017; Hulland et al., 2019).

Evidence is emerging of the mental health impacts of climate change. Tuvaluans are experiencing distress because of the local environmental impacts caused or exacerbated by climate change, and by hearing about the potential future consequences of climate change (Gibson et al., 2020).

15.3.4.3 Water Security

Climate change impacts on freshwater systems frequently exacerbate existing pressure, especially in locations already experiencing water scarcity (Section 15.3.3.2 and Cross-Chapter Box INTERREG in Chapter 16; Schewe et al., 2014; Holding et al., 2016; Karnauskas et al., 2016), making Water Security a Key Risk (KR4 in Figure 15.5) in small islands. Small islands are usually environments where demand for resources related to socio-economic factors such as population growth, urbanisation and tourism already place increasing pressure on limited freshwater resources. In many small islands, water demand already exceeds supply. For example, in the Caribbean, Barbados is utilising close to 100% of its available water resources and St. Lucia has a water supply deficit of approximately 35% (Cashman, 2014). On many Mediterranean islands, water demand regularly outstrips supply as a result of low average precipitation coupled with increasing water demand from economic activities such as irrigated agriculture and tourism (Hof et al., 2014; Papadimitriou et al., 2019).

Population growth plays a strong role in projected future water stress (Schewe et al., 2014). Combining projected aridity change (fractional change compared to historical climatology) with population projections derived from SSP2, shows that the SIDS with high projected population growth rates are expected to experience the most severe freshwater stress by 2030 under a 2°C warming threshold scenario (Karnauskas et al., 2018). For several SIDS (e.g., Belize and Jamaica), increasing aridity change is a prominent exacerbating factor, but for others (e.g., the Solomon Islands and Comoros) population growth is the main factor. A 1°C increase in temperature (from 1.7°C to 2.7°C) could result in a 60% increase in the number of people projected to experience a severe water resources stress in 2043–2071 (Schewe et al., 2014; Karnauskas et al., 2018). Research on Jamaica concluded that the ability of rainwater harvesting to meet potable water needs between the 2030s and 2050s will be reduced based on predicted shorter intense showers and frequent dry spells (Aladenola et al., 2016).

The Caribbean and Pacific regions have historically been affected by severe droughts (Peters, 2015; FAO, 2016; Barkey and Bailey, 2017; Paeniu et al., 2017; Trotman et al., 2017; Anshuka et al., 2018) with significant physical impacts and negative socio-economic outcomes. Water quality is affected by drought as well as water availability. The El Niño related 2015-16 drought in Vanuatu led to reliance on small amounts of contaminated water left at the bottom of household tanks (Iese et al., 2021). The highest land disturbance percentages have coincided with major droughts in Cuba (de Beurs et al., 2019). Drought has been shown to have an impact on rainwater harvesting in the Pacific (Quigley et al., 2016) and Caribbean (Aladenola et al., 2016), especially in rural areas where connections to centralised public water supply have been difficult. Increasing trends in drought are apparent in the Caribbean (Herrera and Ault, 2017) although trends in the western Pacific are not statistically significant (McGree et al., 2016).

Areas where a freshwater lens is thinner are most likely to be impacted by multiple climate stressors, and these areas tend to be in coastal zones where populations are likely to be most concentrated (Holding et al., 2016). In Barbados, where groundwater is relied upon for food production, urban use, and environmental needs, higher food prices are expected in the future if informed land use management and integrated water resources policy implementation are not implemented to manage groundwater in the short term, even with modest climate change threats (Gohar et al., 2019).

15.3.4.4 Fisheries and Agriculture

Fisheries provide small islands with opportunities for economic development, revenues, food security and livelihoods (Bell et al., 2018). Ten Pacific Island countries and territories derive between 5% and >90% of all government revenue (except grants) from access fees paid by industrial tuna-fishing fleets, mainly from distant-water fishing nations (Bell et al., 2018; SPC, 2019). Under a high greenhouse gas emissions scenario (RCP 8.5), the total biomass of three tuna species in the waters of ten Pacific SIDS could decline by an average of 13% (range = −5% to −20%) due to a greater proportion of fish occurring in the high seas (Bell et al., 2021), meanwhile projected increases have been anticipated for Ascension Island and Saint Helena in the South Atlantic (Townhill et al., 2021). Additionally, seafood plays an important role in achieving food security in many islands. In the Pacific, fish protein is estimated to make up 50-90% of animal protein consumption in rural areas, and 40-80% in urban areas (Bell et al., 2009; Hanich et al., 2018) with similar values reported for some Indian Ocean and Caribbean islands (e.g. Maldives, Antigua and Barbuda). It has been suggested that island nations may need to retain more of their tuna catch rather than relying solely on coastal fisheries to achieve food security in the future (Cross-Chapter Box MOVING PLATE in Chapter 5; Bell et al., 2015; Bell et al., 2018). Furthermore, small island fisheries can be severely impacted by extreme events such as TCs, yet rapidly recovering pelagic fisheries can help to alleviate immediate food insecurity pressures in some circumstances, helping to build resilience (Pinnegar et al., 2019).

Observed impacts of climate change on fish and fisheries in small islands include declines in reef-associated species due to coral bleaching or cyclone damage (Robinson et al., 2019; Magel et al., 2020), oceanic-scale shifts in the distribution of large pelagic fish and hence their fisheries (Erauskin-Extramiana et al., 2019), changes to the size structure or breeding behaviour of species (e.g. (Asch et al., 2018)(Sections 3.3.3.2 and 3.4.3.1)). Many studies of future fisheries productivity in a changing climate suggest that yields will fall as a result of ocean productivity reductions, local species extinction and/or migration (Nurse, 2011; Asch et al., 2018; Robinson et al., 2019). Asch et al. (2018) provided future projections for biodiversity and fisheries maximum catch potential in Pacific Island countries and territories. These authors concluded that 9 of 17 Pacific Island entities (Cook Islands, Federated States of Micronesia, Guam, Kiribati, Marshall Islands, Niue, Papua New Guinea, Solomon Islands, and Tuvalu) could experience ≥ 50% declines in maximum catch potential by 2100 relative to 1980–2000 under both an RCP 2.6 and RCP 8.5 scenario (*medium confidence*). In Wallis and Futuna, maximum catch potential was projected to increase slightly (around 10%) by 2050, later declining by the year 2100. Similar projections have now been provided for all countries worldwide, including Pacific, Caribbean, Atlantic, Mediterranean and Indian Ocean small islands (Cheung et al., 2018). The small islands that show the largest anticipated decrease in fisheries maximum catch potential by the end of the century (according to an RCP4.5 and RCP 8.5 scenario) included the Federated States of Micronesia, Kiribati, Nauru, Palau, Tokelau, Tuvalu, São Tomé and Príncipe, whereas some other small islands such as Bermuda, Easter Island (Chile), and Pitcairn Islands (UK), might actually witness increases in fish catch potential (*medium confidence*) (Cheung et al., 2018). Monnereau et al. (2017)showed that for the fisheries sector, small island states are generally more vulnerable to climate change impacts compared to continental least developed countries or coastal states because of their increased reliance on fisheries, the exposure of coastal communities to potential climatic threats and their limited adaptive capacity.

Projected impacts of climate change on agriculture and fisheries pose serious threats to dependent human populations (Ren et al., 2018; Hoegh-Guldberg et al., 2019), making the risk caused to livelihoods a Key Risk in small islands (KR7 in Figure 15.5). On small islands, despite biophysical commonalities (e.g., size and isolation), differences in economic status and level of dependence on agriculture and fisheries produce dynamic climate impacts (Balzan et al., 2018). Climate change is impacting agricultural production in small islands through slow-onset stressors such as rising average temperatures, shifting rainfall patterns, sea level rise and extreme events like TCs. For example, TC Pam, a Category 5 cyclone, devastated Vanuatu in 2015 and caused losses and damages to the agriculture sector valued at USD 56.5 million (64.1% of GDP) (Nalau et al., 2017) and TC Winston Winston in 2016 resulted losses and damages on the agriculture sector in Fiji valued at USD 254.7 million (Iese et al., 2020). In 2017, total loss and damage associated with hurricane Maria (category 5) amounted to 224% of Dominica's 2016 GDP (Barclay et al., 2019). Losses and damage in agriculture often led to people eating imported processed foods affecting their diet and nutrition (Haynes et al., 2020).Small Islands' communities are also witnessing the indirect effects of the covid-19 pandemic on agricultural systems (Hickey and Unwin, 2020). However, the limited diversity of agriculture production and reduced household incomes are contributing to low diet diversity (Iese et al., 2020). Bell and Taylor (2015) assessed the effects of climate change on specific sectors of agriculture in the Pacific islands region and found that, by 2090, staple food crops of taro, sweet potato, and rice are expected to suffer from moderate to high impact. Among export crops, coffee is expected to sustain the most significant impact due largely to increased temperatures in the highland areas of Papua New Guinea – a high production area (Bell et al., 2016). Livestock is an important protein source in some small islands and is particularly vulnerable to changes in temperature through heat stress (Bell and Taylor, 2015; Lallo et al., 2018). With the concentration of island people along (often reef-fringed) coasts, there is a comparatively large dependence on nearshore marine foods and coastal agricultural systems (Ticktin et al., 2018).

In the Caribbean, additional warming by 0.2°–1.0°C, could lead to a predominantly drier region (5%–15% less rain than present-day), a greater occurrence of droughts (Taylor et al., 2018) along with associated impacts on agricultural production and yield in the region (Gamble et al., 2017; Hoegh-Guldberg et al., 2019; Nicolas et al., 2020). Crop suitability modeling on several commercially important crops grown in Jamaica found that even an increase less than + 1.5 °C could result in a reduction in the range of crops that farmers may grow (Rhiney et al., 2018).

Sugar yield in Fiji could decline by 2–14% under projected scenarios (McGree et al., 2020). Farmers in some small islands have utilised Indigenous knowledge systems built on local ontology to sharpen their sensitivity to environmental conditions (Shah et al., 2018). However, projected climate change across the Pacific could undermine climate-sensitive agricultural livelihoods and exacerbate food insecurity challenges (McCubbin et al., 2017; Campbell et al., 2021).

Projected climate impacts on island agroecosystem services could accentuate a myriad of social and ecological risks (Campbell, 2021). Without proactive farm management practices, the projected impacts of climate change on drought patterns is a major threat to cocoa pollination services (Arnold et al., 2018). Many tropical island agroforestry crops are completely dependent on insect pollination and it is therefore important to understand the climatic drivers of changing conditions related to pollinator abundance. Coastal agroforestry systems in small Pacific islands are vital to national food security but native biodiversity is rapidly declining (Ticktin et al., 2018). Biodiversity loss from traditional agroecosystems is a major threat to food and livelihoods security in SIDS (UNEP, 2014a). Additionally, while coastal-lowland salinisation and more-frequent flooding attributable to SLR have impacted coastal agriculture on some islands (Cruz and Andrade, 2017; Wairiu, 2017), stronger TCs can sometimes shock island terrestrial food production warranting reconfiguration (Mertz et al., 2010; Duvat et al., 2016; Chakrabarti et al., 2017). Calls to conserve associated environments and to make terrestrial food production on islands more resilient to climate-driven shocks underscore concern about future food security (Connell, 2013; de Scally, 2014). Implicit in the latter is reversing the decades-long loss of Indigenous knowledge about food production in many island societies and incorporating it into future strategies (Mercer et al., 2014b; Janif et al., 2016).

15.3.4.5 Economies

Small-island economies vary greatly in their nature, history/trends, and viability under a changed climate. As elsewhere, few small island economies are overseen by governments that are adequately prepared for the economic impacts of climate change over the next few decades (Connell, 2013; Hay, 2013). In particular, the lack of diversity that characterizes most small-island economies means they are especially vulnerable to global (climate-driven) shocks (Cross-Chapter Box DEEP in Chapter 17), be these the impacts of extreme events or more gradual longer-term change, which makes the maintenance of traditional mechanisms for coping with such shocks in many island societies all the more important (Granderson, 2017; Wilson and Forsyth, 2018; Nunn and Kumar, 2019b). As a result, the risk from climate change to economies constitutes a Key Risk (KR7 in Figure 15.5) in small islands.

Many island environments have been commercially exploited by external interests for much of their recent history. This is especially common for timber, the wholesale removal of forests, especially on tropical islands, exposing land to heavy rain that leads to denudation and increases lowland sedimentation (Wairiu, 2017; Eppinga and Pucko, 2018). Negative aspects of both processes will be exacerbated by climate change, demonstrating the practical need for reforestation in many island contexts (Thomson et al., 2016).Some small-island economies are sustained by extractive industries such as mining, creating dependencies that lead to their environmental impacts being downplayed (Tserkezis and Tsakanikas, 2016; Shepherd et al., 2018). It is important to address these impacts as they will add to negative impacts of climate change (Clifford et al., 2019).

Many small-island economies are sustained by tourism and have invested heavily in associated infrastructure and capacity building (Cannonier and Burke, 2018). Some rural island communities have become dependent on tourism to the point that it would be difficult to revert to subsistence living (Lasso and Dahles, 2018). Coast-focused (beach-sea) tourism in island contexts is already being impacted by beach erosion, elevated high SST causing coral bleaching, and associated marine-biodiversity loss, as well as more intense TCs (Tapsuwan and Rongrongmuang, 2015; Parsons et al., 2018; Wabnitz et al., 2018). The Covid-19 pandemic travel disruption significantly affected Caribbean islands tourism sector by reducing incomes that would have been used to enhance climate resilience (Sheller, 2020). Many tourism interests downplay the impacts and future risks from climate change (Shakeela and Becken, 2015), a position that may be borne out by sustained/rising demand for small island vacationing in some locales (Katircioglu et al., 2019). A way forward is for island tourism to emphasize its low-carbon and sustainable attributes, and to encourage smaller-scale eco-friendly holiday opportunities (Lee et al., 2018), in other words for island nations to embrace a 'blue economy' in line with SDG14 to conserve and utilise their oceans for sustainable futures (Hampton and Jeyacheya, 2020; Hassanali, 2020).

Given the high cost of imported goods, especially foodstuffs, larger island jurisdictions are striving to transform their economies to favour locally produced or locally constituted materials that employ local people and reduce their cost of living. The exposure of this component of island economies varies, yet manufacturing/commercial operations are usually found in the lowest-lying areas, often on reclaimed lands. This makes them especially vulnerable to rising sea level, part of a larger issue around the disproportionate exposure of infrastructure on small islands to climate change (Fakhruddin et al., 2015; Kumar and Taylor, 2015).

It is challenging to disentangle the role of climate change from that of globalisation and development in recent changes to human livelihoods on small islands, given that the latter have characterised many – especially SIDS – within the last few decades. However, recent climate change is clearly implicated in livelihood deterioration in many island contexts (Hernandez-Delgado, 2015; Nunn and Kumar, 2018). For example, livelihood impacts of climate-driven stressors (including shoreline/riverbank erosion, flooding and erratic rainfall) in three Mahishkhocha island-chars (river-mouth sand islands of Bangladesh) have been amplified by inadequate/misguided policy (Saha, 2017).The subordination of IKLK in favour of external adaptation strategies has accelerated livelihood decline in many island contexts (Wilson and Forsyth, 2018). Although economic and financial development has the potential to reduce environmental (and livelihood) degradation in SIDS (Seetanah et al., 2019), it is also clear that uneven development can steepen core-periphery disparities, especially in archipelagic contexts, resulting in deteriorating rural/peripheral livelihoods at the expense of improving urban ones (Wilson, 2013; Sofer, 2015) and increased rural-urban migration (Birk and Rasmussen, 2014; Connell, 2015).

15.3.4.6 Migration

Climate-related migration is considered to be a particular issue for small islands because changes in extreme events and slow-onset changes affect increasingly highly exposed and vulnerable low-lying coastal populations, therefore causing a threat to small island habitability (KR9 in Figure 15.5) (Storey and Hunter, 2010; Kumar and Taylor, 2015; Duvat et al., 2017b; Weir and Pittock, 2017; Hoegh-Guldberg et al., 2018; Mycoo, 2018a; Rasmussen et al., 2018). A typology of climate-related migration is provided in Cross-Chapter Box MIGRATE in Chapter 7. It is assumed that climate-related migration will increase in small islands, however, as is the case globally, the causes, form and outcomes are highly context specific. Types of climate-related migration occur across a continuum of agency from involuntary displacement at one end to voluntary movement to strategically reduce risks and planned resettlement at the other end (Section 15.5.1, also see Chapter 7; Birk and Rasmussen, 2014; Betzold, 2015; McNamara and Des Combes, 2015; Gharbaoui and Blocher, 2016; Stojanov et al., 2017; Weir, 2020).

Studies do not provide sufficiently robust evidence to attribute the various forms of migration to anthropogenic climate change directly on small islands or to accurately estimate the current number of climate-related migrants (see Chapter 7). Climate events and conditions strongly interact with other environmental stressors and economic, social, political and cultural reasons for migrating (*robust evidence, high agreement*) (Birk and Rasmussen, 2014; Campbell and Warrick, 2014; Laczko and Piguet, 2014; Marino and Lazrus, 2015; Connell, 2016; Weber, 2016b; Stojanov et al., 2017; Cashman and Yawson, 2019).

Despite difficulties with attribution, the literature establishes that climate variability and extreme events and broad environmental pressures have contributed to some degree to human mobility on small islands over time (*medium evidence, high agreement*) (Birk and Rasmussen, 2014; Campbell, 2014a; Campbell and Warrick, 2014; Donner, 2015; Kelman, 2015a; Connell, 2016; Stojanov et al., 2017; Barnett and McMichael, 2018; Martin et al., 2018) and these studies can provide analogues from which to inform climate-migration responses (Birk and Rasmussen, 2014; Kelman, 2015a; Connell, 2016).

Similarly, studies do not provide robust evidence to project how the full range of climate drivers may influence migration patterns on small islands into the future, although studies are emerging that estimate populations affected as a consequence of projected SLR. Rasmussen et al. (2018) estimated current populations of the world that are potentially subject to permanent inundation from projected local mean SLR associated with global mean surface temperature stabilisation targets of 1.5°C, 2.0°C, and 2.5°C occurring at 2100. For the affected land area and population, this analysis included a subset of 58 SIDS, as defined by the United Nations, for which the results are shown in Table 15.4.

Table 15.4: Global mean sea level rise (SLR) at 2100 projections and associated population of SIDS exposed to permanent inundation for global mean surface temperature stabilisation targets of 1.5°C, 2.0°C and 2.5°C. Rasmussen et al. (2018)

Stabilised Warming at 2100[a]	1.5°C		2.0°C		2.5°C	
Percentile	*50*	*5th–95th*	*50th*	*5th–95th*	*50th*	*5th–95th*
Global-mean SLR (cm) by percentile[b]	48	28–82	56	28–96	58	37–93
SIDS population exposure (thousands) by percentile[c]	400	300-560	420	300-640	430	320-630

Table Notes:
(a) Above pre-industrial level.
(b) Values are centimeters above 2000 current era baseline.
(c) Potentially affected population due to local mean SLR. Local mean SLR projections used for individual SIDS take account of variations from the global mean due to factors such as glacial isostatic adjustment, gravitational changes from ice melting, deltaic subsidence and tectonic movements.

The aggregate figures of population that could potentially be affected by permanent inundation shown in Table 15.4 and Figure 15.3 mask important differences in relative exposure between individual SIDS. Further, population affected by permanent inundation does not take into account the change in the frequency of ESL events and associated water-level attenuation (as per Vafeidis et al., 2019), nor does it account for adaptation measures that may alleviate impacts, future population growth, or the extent to which populations could adaptively migrate (Section 15.5.3). However, Rasmussen et al. (2018)'s analysis shows that comparatively small changes in mean sea level can result in large increases in the frequencies of ESL events and, hence, the risk of coastal flooding of inhabited land, suggesting many areas of SIDS may become uninhabitable well before the time of permanent inundation (see also studies referenced in Section 15.3.3.1.1). A similar conclusion is drawn by Kulp and Strauss (2019) who show that land area home to 10% or more of the population of many SIDS is at risk of chronic coastal flooding or permanent inundation by 2100.

Duvat et al. (2021a) employed an integrated systems approach to analyse future risk to habitability in atoll islands, taking into account changes in various ocean and atmospheric climate drivers and a moderate adaptation scenario (i.e., adaptation responses that remain similar in nature and magnitude to currently observed responses). They found that, compared to present-day risk, additional risk to habitability in Male, Maldives, and Fogafale, Tuvalu, is minimal under a low emissions scenario (RCP2.6) at 2050, although it may become moderate for Male and high for Fogafale by 2090. Under a worse case emissions scenario (RCP 8.5), future risk to habitability in these two urban islands may increase slightly in 2050, but may increase to moderate-to-high (for Male') and high-to-very high (for Fogafale) by 2090.

Even where settlement locations and livelihoods remain secure, an increase in health diseases, decrease in the availability of potable water, and increasing exposure to extreme events may reduce habitability (Section 15.3.4.9.2; Campbell and Warrick, 2014; Storlazzi et al., 2018). For example, the Fijian coastal community of Vunidogoloa made the decision to relocate in response to regular inundation during high tides. Raising houses on stilts and constructing a seawall failed to prevent regular flood damage to buildings and the entire community eventually relocated as a 'last resort' adaptation measure to a site within customary land. The availability of customary land for the new site was a key factor of success in this relocation example although this will not guarantee success in every case as relocation may expose communities to new risks (McNamara and Des Combes, 2015; Piggott-McKellar et al., 2019a).

15.3.4.7 Culture

Small island societies have developed IKLK based responses to living in dynamic environments susceptible to climate variability and extremes, which are based in broader systems of culture and heritage (*high confidence*) (Barnett and Campbell, 2010; Lazrus, 2015; Nunn et al., 2017b; Bryant-Tokalau, 2018b; Nalau et al., 2018b; Perkins and Krause, 2018). As expanded upon in Section 15.6.5 cultural resources are thought to play an important role in climate change adaptation on small islands through contributing to adaptive capacity and resilience (McMillen et al., 2014; Petzold and Ratter, 2015; Nunn et al., 2017b; Warrick et al., 2017; Falanruw, 2018; Mondragón, 2018; Neef et al., 2018; Parsons et al., 2018; Perkins and Krause, 2018; Hagedoorn et al., 2019; 2020a) (*robust evidence, medium agreement)*. Thus, loss of culture (KR8 in Figure 15.5) threatens adaptive capacity.

Some studies from the Pacific suggest that climate-migration linked to reduced habitability (Section 15.3.4.6) can have particularly severe cultural implications in a small island context where community solidarity and cohesion linked to place-based identity are important aspects of adaptive capacity (Hofmann, 2014; Lazrus, 2015; Warrick et al., 2017). In Federated States of Micronesia, land is owned through the matrilineal system and hence puts women in the centre of decision-making. The deterioration and loss of land (through saltwater intrusion, flooding, drought, erosion) not only can lead to economic deprivation but it also compromises cultural identities: “Where land signifies political, social, and economic well-being, becoming bereft of land cuts off an important thread of people’s sense of belonging” (Hofmann, 2017, p. 82) particularly for Chuuk women. Land degradation and loss involves the “interruption to the matrilineal transmission of land” (Hofmann, 2017;p. 82), the loss of identities, relationships, and their customary authority.

The unquantifiable and highly localised cultural losses resulting from climate drivers are less researched and less acknowledged in policy than physical and economic losses (Karlsson and Hovelsrud, 2015; Thomas and Benjamin, 2018a). In the Bahamas, prolonged displacement of the entire population of Ragged Island following Hurricane Irma (2017) highlighted the cultural losses that can result from climate-induced displacement from ancestral homelands. Threats to identity, sense of place and community cohesion resulted from displacement, although all were important foundational features of the Islanders’ self-initiated rehabilitation efforts and eventual return. Nonetheless, non-economic losses were not accounted for by policy addressing displacement (Thomas and Benjamin, 2018a). In the case of Monkey River Village in Belize, coastal erosion is threatening the community’s cemetery. Residents place significant spiritual and emotional value on the cemetery which serves important community functions, and thus, threats to it are perceived to be serious and necessary to be taken into account in any planned response (Karlsson and Hovelsrud, 2015). A similar situation exists on Carriacou in the West Indies where culturally and historically significant archaeological sites are being lost due to coastal erosion caused by a combination of sand mining and extreme climate-ocean events exacerbated by SLR (Fitzpatrick et al., 2006).

Population and settlement concentration in coastal areas and high exposure to climate-driven coastal hazards on small islands mean that threats to tangible cultural heritage (archaeological sites, buildings, historic sites, UNESCO World Heritage Sites etc.) are high (Marzeion and Levermann, 2014; Reimann et al., 2018), although few studies examine this issue specifically in a small island context. On the island of Barbuda, archaeological sites containing important information on historical ecology and climatic shifts are at risk from coastal erosion and hurricanes. This loss of heritage represents identity loss, as “learning about the past is a crucial exploration of self that grounds and connects people to places” (Perdikaris et al., 2017)(p. 145). Loss and damage to heritage sites may also impact tourism and thus have significant economic impacts for narrow small island economies (Section 15.3.4.5).

15.3.4.8 Transboundary Risks/Issues

Inter-regional transboundary impacts are those generated by processes originating in another region or continent well beyond the borders of an individual archipelagic nation or small island. Intra-regional transboundary impacts originate from a within-region source (e.g., the Caribbean). Some transboundary processes may have positive effects on the receiving small island or nation, though most that are reported have negative impacts (Table 15.5).

Table 15.5: Summary of inter- and intra-regional transboundary risks and impacts on small islands
[INSERT TABLE 15.5 HERE]

[START BOX 15.1 HERE]

Box 15.1: Key Examples of Cumulative Impacts from Compound Events: Maldives Islands and Caribbean Region

Cumulative Impacts of the Compound Events of the 1998-2016 Period in the Maldives Islands

Between 1998 and 2016, the Maldives Islands were affected by three major climate events, including the 1997-1998 ENSO event, the 2007 flood event and the 2016 ENSO event, and by one tectonic event, the 2004 Indian Ocean Tsunami (Morri et al., 2015). These events illustrate the cumulative and cascading risks that a series of events may cause in reef-dependent atoll contexts (Figure Box15.1).

The 1997-1998 ENSO event was severe in the Maldives and as a result the living coral cover dropped to <10% (Bianchi et al., 2003). Recovery was still in progress in 2004 when the tsunami caused further (although not quantitatively assessed (Gischler and Kikinger, 2006)) damage to the reef ecosystem. Post-1998 recovery ultimately took 15 years, (i.e., longer than following the 1987 ENSO event, after which recovery had only taken a few years) and also longer than in the neighbouring undisturbed Chagos atolls, thereby suggesting the alteration of the recovery capacity of the reef ecosystem by human-induced reef degradation and climate change (Morri et al., 2015; Pisapia et al., 2017). Mid-2016, a new ENSO event occurred, which reduced living coral cover by 75% (Perry and Morgan, 2017). Future recovery of the reef ecosystem, which is critical to both current livelihoods and economic activities (especially diving-oriented tourism and fishing) and to long-term island persistence, will mainly depend first on the frequency and magnitude of future bleaching events, which are expected to increase due to ocean warming, and second on the highly variable effects of anthropogenic disturbances locally (Perry and Morgan, 2017; Pisapia et al., 2017; Duvat and Magnan, 2019b).

Additionally, the 2004 Indian Ocean tsunami (Magnan, 2006) and the 2007 flood (Wadey et al., 2017) caused damage totalling 62% of the country's GDP (Luetz, 2017). The tsunami also downgraded the Maldives (now a middle-income country) to the Least Developed Countries category and caused within-country migration, with 30,000 people (9.6% of the country's population) displaced (Republic of Maldives, 2009). These successive events, which had cumulative devastating effects on the reef ecosystem and cascading effects on health and well-being, livelihoods and economy, highlighted the risk posed by limited recovery time to the whole social-ecological system as well as the detrimental effect of local human disturbances on reef recovery.

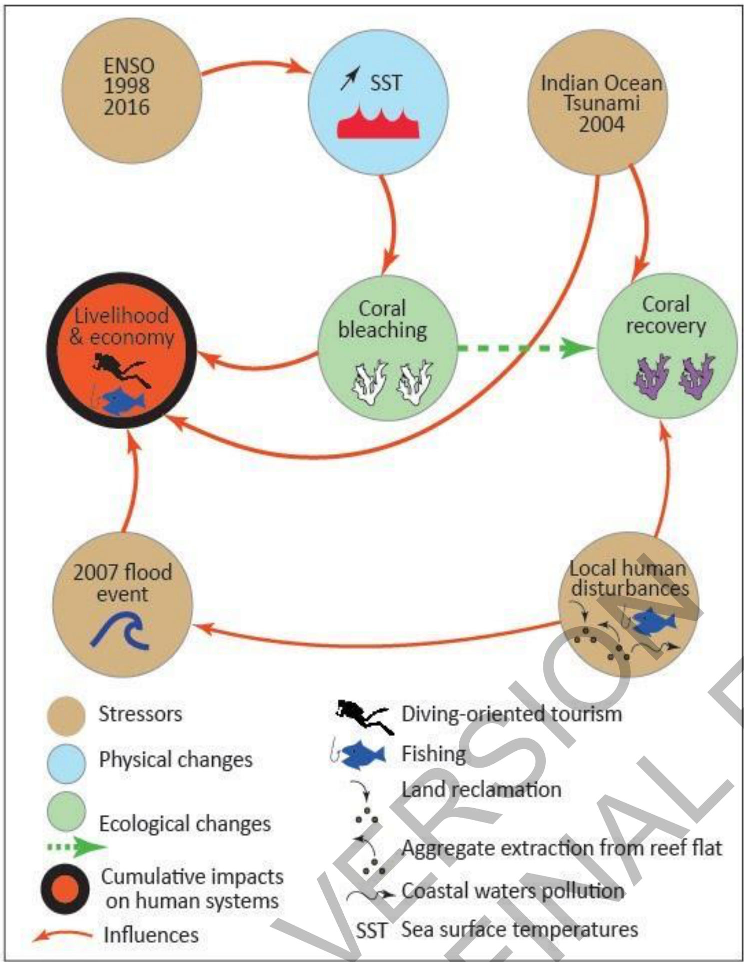


Figure Box15.1.1: Cascading and cumulative impacts of the compound events of the 1998-2016 period in the Maldives Islands.

Cumulative Impacts of the 2017 Hurricanes in the Caribbean Region

Among the 29 Caribbean SIDS, 22 were affected by at least one category 4 or 5 TC in 2017. These events highlighted how the pre-cyclone high exposure and vulnerability of these islands and their populations has caused a "cumulative community vulnerability" (Lichtveld, 2018, p. 28) that has amplified the impacts of these TCs, which will in turn increase the long-term vulnerability of affected islands. The exposure of these islands over their entire surface, combined with the concentration of people, and infrastructure, utilities and public services in flood-prone coastal areas, inadequate housing, limited access to healthy food and transportation, and unpreparedness explains widespread-to-total devastation (Shultz et al., 2018; Briones et al., 2019). The destruction of transport systems (Lopez-Candales et al., 2018) and island supply chains (Kim and Bui, 2019), which heavily depend on ports, roads, power and communications, made rescue logistically complex, explaining the lack of freshwater, food supplies, medications and fuel on some islands for several weeks after the event. This cumulative vulnerability caused "cascading public health consequences" (Shultz et al., 2018, p.9), including delayed (i.e., over the next year) mortality, physical injury during the clean-up and recovery phase, and increased the risk of chronic, vector-borne, contaminated water-related diseases, and mental sequelae (Kishore et al., 2018; Ferre et al., 2019).

The loss of mangroves (Branoff, 2018; Walcker et al., 2019; Taillie et al., 2020) and terrestrial forests (Eppinga and Pucko, 2018; Feng et al., 2018; Hu and Smith, 2018; Van Beusekom et al., 2018) exacerbated the cyclone-induced economic crisis. In the most affected islands, the destruction of buildings and outmigration generated a significant loss of tangible (e.g., museums) and intangible (e.g., traditional artistry) cultural heritage (Boger et al., 2019). Prolonged displacement of entire island populations (e.g., Ragged Island, the Bahamas; Barbuda) caused "non-economic loss and damage", including threats to health and well-being, and loss of culture, sense of place and agency (Thomas and Benjamin, 2019), which may further exacerbate the long-term vulnerability of concerned communities.

In early 2020, while island communities were still recovering from the 2017 hurricanes, the COVID-19 pandemic caused the closure of global transportation, with devastating socioeconomic impacts on tourism-dependent Caribbean economies (Sheller, 2020), illustrating how compounding crises increase island vulnerability to both climate and non-climate related events.

[END BOX 15.1 HERE]

[START BOX 15.2 HERE]

Box 15.2: Loss and Damage and Small Islands

Loss and damage has a range of conceptualizations (Section 1.4.4.2; Cross-Chapter Box LOSS in Chapter 17) and is a critical issue for many small islands, closely related to issues of climate justice (Section 15.7). Small islands are already experiencing an array of negative climate change impacts while climate risks are projected to increase as global average temperatures rise (Section 15.3, 16.2; Cross-Chapter Paper 2). Barriers and limits to adaptation also contribute to greater levels of both economic and non-economic loss and damage for small islands (Sections 15.6, 16.4).

For SIDS in particular, loss and damage has negative implications for sustainable development (Benjamin et al., 2018). The costs of loss and damage, particularly from extreme events, can deplete national capital reserves (Noy and Edmonds, 2019). Thomas and Benjamin (2017) show how loss and damage can lead to an 'unvirtuous cycle of climate-induced erosion of development and resilience'. In this cycle, addressing loss and damage strains limited national resources, diverting public funding and other resources to address negative climate impacts. This in turn reduces resources and capacities which could be allocated to adaptation, building resilience and sustainable development, thereby increasing vulnerability to climate change and leading to further loss and damage where the cycle begins again. The cascading and cumulative impacts of extreme events experienced in Pacific and Caribbean SIDS exemplify that this cycle may already be in effect.

In addition to the strain on national resources that loss and damage currently presents, credit ratings of SIDS have recently begun to include vulnerability to climate change, which may have negative impacts on their abilities to borrow external funds, attract foreign investment or access concessional financing (Buhr et al., 2018; Volz et al., 2020). Costs of addressing loss and damage may also affect the ability of SIDS to repay external debt, thus endangering eligibility for future access to funding (Baarsch and Kelman, 2016; Klomp, 2017; Shutter, 2020). These factors may place SIDS in situations where they face mounting costs of climate change with eroding capacities and resources to address loss and damage.

In the international policy arena, small islands - as part of Alliance of Small Island States (AOSIS) - have been strong advocates for including loss and damage in the United Nations Framework Convention on Climate Change (UNFCCC); highlighting the increasing and irreversible risks that climate change poses for islands in particular (Roberts and Huq, 2015; Adelman, 2016; Mace and Verheyen, 2016). AOSIS, along with other developing countries and groups, have advocated that there is a pressing need for finance and resources to address loss and damage as well as greater integration of loss and damage in the UNFCCC and the Paris Agreement, including in capacity building, technology and the global stocktake (Benjamin et al., 2018; Nand and Bardsley, 2020).

[END BOX 15.2 HERE]

15.3.4.9 Key Risks in Small Islands

15.3.4.9.1 Key Risk approach

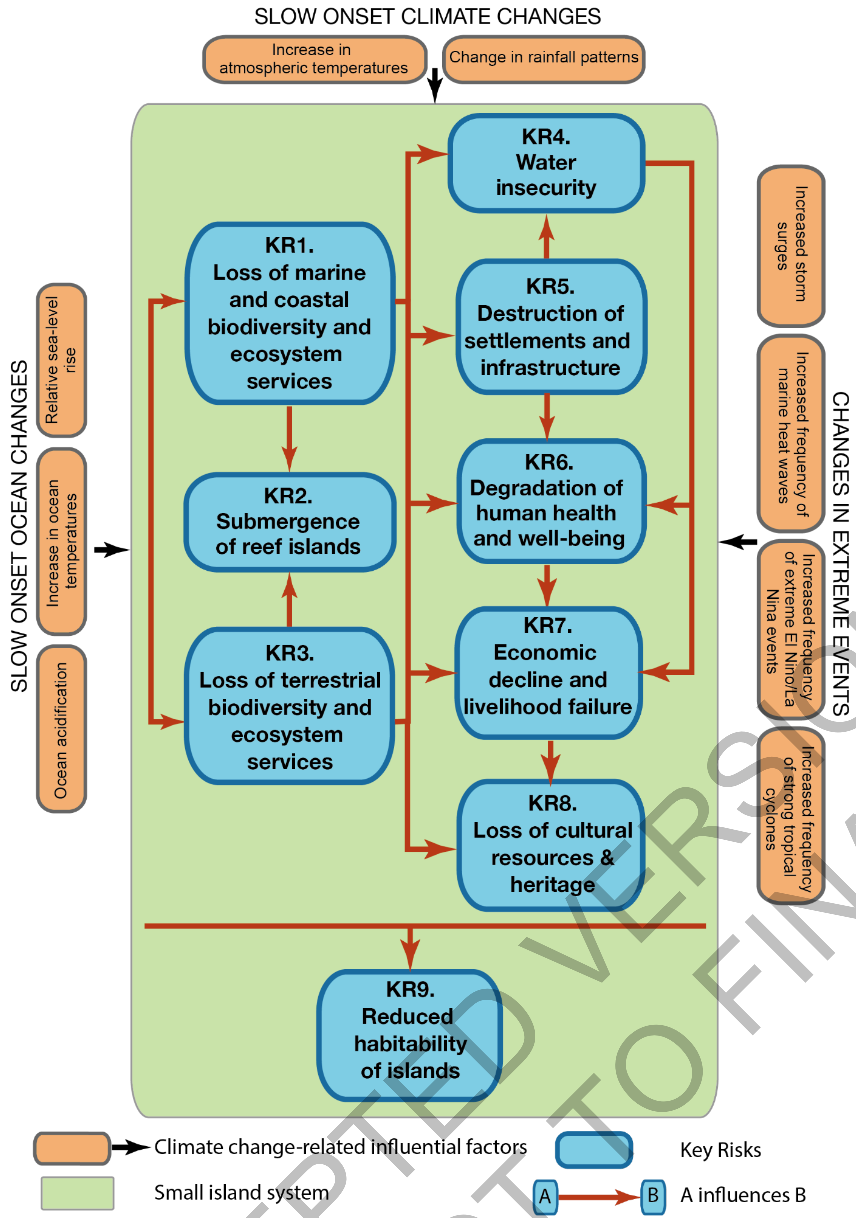
This section builds on cross-chapter work led by Chapter 16 of the WGII AR6 Report aimed at identifying and assessing Key Risks across sectors and regions (Section 16.5 and Supplementary Material 16.A.2). Key Risks (KRs) are the risks of most pressing concern that are caused or exacerbated by climate change in a given region. A KR is defined as a 'potentially' severe risk, which can either be already severe or projected to become severe in the future, as a result of (i) changes in associated climate-related hazards and/or the exposure and/or vulnerability of natural and human systems to these hazards, and/or of (ii) the adverse consequences of adaptation or mitigation responses to the risk. In line with the guidelines used in the WGII AR6 Report, the identification of KRs in small islands is based on the chapter authors' expert judgment, using scientific literature and five types of criteria: (1) Importance of the affected system or dimension of the system, which is a value judgment left to readers to make; (2) Magnitude of adverse consequences, based on their pervasiveness, degree and irreversibility, and on the potential for impact thresholds and cascading effects across the system; (3) Likelihood of adverse consequences, although this probability is rarely quantifiable for small islands due to limited downscaled data at a small island level; (4) Temporal characteristics of the risk, including its period of emergence, persistence over time and trend; and (5) Ability to respond to the risk, with the severity of the risk being inversely proportional to this ability.

15.3.4.9.2 Key Risks in small islands

Slow onset climate and ocean changes, and changes in extreme events, are expected to cause and/or to amplify nine KRs in small islands, through both direct (e.g., decrease in rainfall will increase water insecurity) and indirect, that is, cascading effects: for example, loss of terrestrial biodiversity and ecosystem services will increase water insecurity, which will in turn cause the degradation of human health and well-being (Figure 15.5, Table 15.6 and Table 16.A.4 in Chapter 16 Supplementary Material).

These KRs include loss of marine and coastal biodiversity and ecosystem services (*high confidence*) (KR1; for details on KR coverage, see Section 15.3.3.1); submergence of reef islands (*low confidence*) (KR2; Section 15.3.3.1.1); loss of terrestrial biodiversity and ecosystem services (*high confidence*) (KR3; Section 15.3.3.3); water insecurity (*medium-high confidence*) (KR4; Section 15.3.4.3); destruction of settlements and infrastructure (*high confidence*) (KR5; Section 15.3.4.1); degradation of human health and well-being (*low confidence*) (KR6; section 15.3.4.2); economic decline and livelihood failure (*high confidence*) (KR7; Sections 15.3.4.4 and 15.3.4.5); and loss of cultural resources and heritage (*low confidence*) (KR8; Section 15.3.4.7).

Risk accumulation and amplification through cascading effects from ecosystems and ecosystem services to human systems will likely cause reduced habitability of some small islands (*high confidence*) identified as the overarching KR (KR9). Habitability is understood as the ability of these islands to support human life by providing protection from hazards which challenge human survival; by assuring adequate space, food and freshwater; and by providing economic opportunities, which contribute to health and well-being; recognizing that both supportive ecosystems and socio-cultural conditions (i.e. beliefs and values, institutions and governance arrangements, sense of community and attachment to place) play a critical role in habitability (Duvat et al., 2021a). The reduction of island habitability is expected to cause increased migration, along the above-mentioned involuntary displacement to planned resettlement spectrum (Section 15.3.4.6), which may eventually lead to population movements from exposed areas and depopulation of some islands. This risk is the highest for atoll nations, where some islands might become uninhabitable over this century (Section 15.3.4.6; Storlazzi et al., 2018; Duvat et al., 2021a). Despite a lack of literature assessing the risk of reduced habitability in non-atoll islands, the latter are also expected to experience decreased habitability, especially in their coastal areas.



See text sections for detailed description of KR coverage.

Figure 15.5: Key Risks in small islands. KR1 to 8 are interconnected as shown by arrows, which causes risk accumulation leading to reduced island habitability. The main interconnections are shown in this figure: for example, loss of marine and coastal and terrestrial biodiversity and ecosystem services (KR1 and KR3, respectively) are projected to cause the submergence of reef islands (KR2), water insecurity (KR4), destruction of settlements and infrastructure (KR5), degradation of human health and well-being (KR6), economic decline and livelihood failure (KR7), and loss of cultural resources and heritage (KR8). Importantly, Key Risks result from both direct effects (e.g. decrease in rainfall will increase water insecurity) and indirect effects (e.g. loss of terrestrial biodiversity and ecosystem services will increase water insecurity, which will in turn cause the degradation of human health and well-being).

15.4 Detection and Attribution of Observed Impacts of Climate Change on Small Islands

As highlighted in AR5, detection of climate change impacts on the fragile environments of small islands is challenging because of other non-climate drivers that affect small islands. Determination of attribution to incremental change of climate drivers is also challenging because of the natural climate variability. Therefore, there is limited scientific literature on observed impacts and attribution. A synthesis of findings on the impacts of climate change (Sections 15.3.3 and 15.3.4) shows that there is more information on impacts on ecosystems compared to human systems. There is *high confidence* in attribution to climate change of impacts on the coastal and marine as well as terrestrial ecosystems (Hansen and Cramer, 2015; Shope et al., 2016; van Hooidonk et al., 2016; Hoegh-Guldberg et al., 2017; Hughes et al., 2017b; Mentaschi et al., 2017; Shope et al., 2017; Vitousek et al., 2017; Wadey et al., 2017; Ford et al., 2018; Hughes et al., 2018; IPCC, 2018; Storlazzi et al., 2018; Bindoff et al., 2019) and *medium confidence* in attribution to climate change of impacts on livelihoods, economics and health (Figure 15.6; McIver et al., 2016; Eckstein et al., 2018; Santos-Burgoa et al., 2018; Schütte et al., 2018; WHO, 2018).

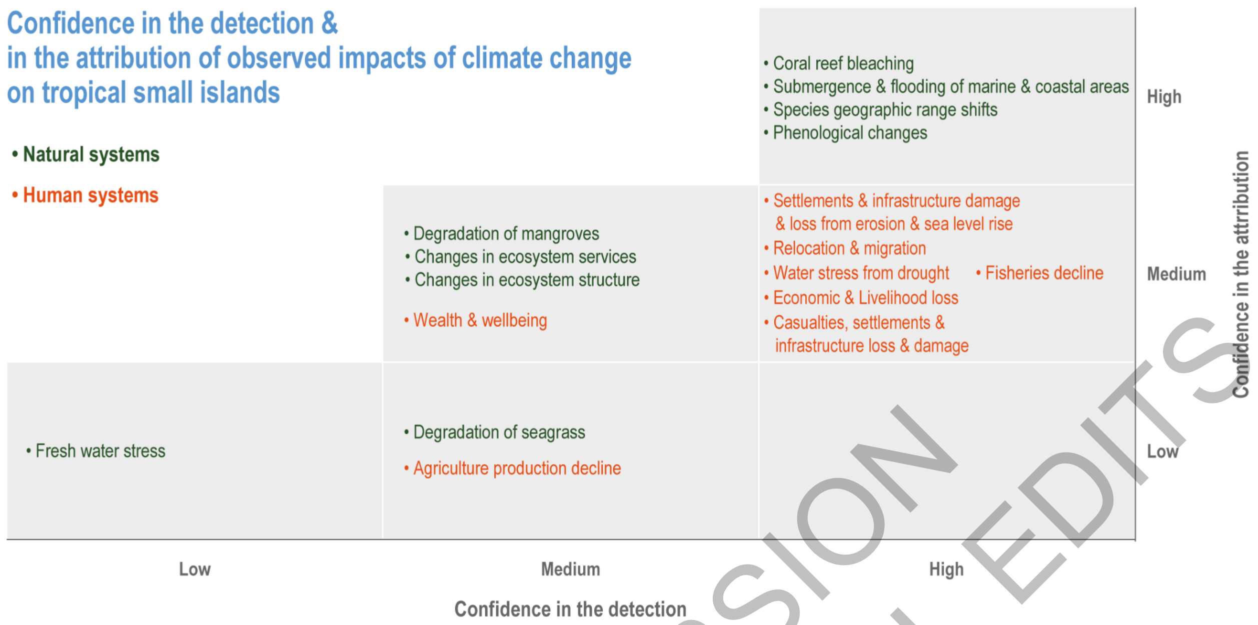


Figure 15.6: A comparison of the degree of confidence in the detection of observed impacts of climate change on tropical small islands with the degree of confidence in attribution to climate change drivers.

As Figure 15.6 shows there is *high confidence* that climate change causes changes in terrestrial ecosystems as well as coral reef bleaching through increases in sea surface temperature and submergence and flooding of coastal areas through sea level rise and increased wave height. With respect to casualties, settlements and infrastructure loss and damage, economic and livelihood loss, although confidence in detection is high, there is at present *medium confidence* in the attribution to climate change. *Medium confidence* in attribution frequently arises owing to the limited research available on small island environments.

15.5 Assessment of Adaptation Options and Their Implementation

Since AR5, small islands have experimented with new adaptation options, which has increased the lessons learnt from on-the-ground practices in these settings. Figure 15.7 shows some of the adaptation options that are being experimented with in small islands. This section covers most common adaptation actions and approaches across small islands and assesses the many constraints, enablers and limits to adaptation. Adaptation plays also a key role in climate resilient development and the insights emerging from small islands on this topic are discussed after the adaptation section.

15.5.1 Hard Protection

Seawalls have been a popular coastal protection measure on islands (Figure 15.7). An analysis of National Communications shows that 28% of coastal protection actions are seawalls, followed by breakwater structures and coastal protection units (Robinson, 2017a). Coastal protection infrastructure has been heavily invested, for example in the Caribbean region (Mycoo, 2014b) and Cuba (Mycoo, 2014a). A similar situation applies in many Indian Ocean islands, where coastal protection strategies are manifested by hard shoreline structures, many of which are proving challenging to maintain (Naylor, 2015; Betzold and Mohamed, 2017; Magnan and Duvat, 2018). In the Pacific the situation is different given that many islands have been occupied for millennia by indigenous communities with extant knowledge for coping with adversity (Granderson, 2017). The latter generally favours ‘soft’ shoreline structures for coastal protection although the building of seawalls has been rapid, especially in urban islands (Umeyama, 2012; Duvat, 2013; Magnan et al., 2018; Morris et al., 2018), and also in some rural islands (e.g., Tubuai, French Polynesia (Salmon et al., 2019)).

Many rural communities have uncritically emulated structures in urban contexts built and maintained with external finances. As a result, in many Pacific SIDS, seawalls have collapsed without additional funding available for repairs (Nunn and Kumar, 2018; Piggott-McKellar et al., 2020; Nunn et al., 2021). Similar cases have been recorded along the coast of Puerto Rico (Jackson et al., 2012) while on Indian Ocean islands (e.g., Seychelles), the shorelines are littered with broken seawalls and groynes (Duvat, 2009). In Samoa, seawalls close to Apia need constant investments to remain viable.

On small islands, another widespread issue with seawalls and other hard shoreline structures is that they invariably shift problems of shoreline erosion and lowland inundation elsewhere (Donner and Webber, 2014). Even surrounding entire islands with such structures, as has happened on Male' (Maldives), is not a long-term solution because of incidences of localised seawall collapse that can spread quickly if not addressed immediately (Naylor, 2015). Hard structures for coastal protection will become increasingly ineffective in the future, demonstrating the need for adaptation along most island coasts to become more transformative than has been the case over the past few decades. In the Bahamas, it has been suggested that coastal protection structures and strategies are implemented through "a rather piecemeal approach of single projects and small patches, partially resulting in maladaptation by further increasing processes of erosion" (Petzold et al., 2018)(p. 95). In the village of Lalomalava, Samoa, national adaptation funding was spent on erecting a seawall to protect the village, but the wall was not long enough to protect the whole village, leading some families and properties to face increasing impacts from large waves (Crichton and Esteban, 2018).

15.5.2 Accommodation and Advance as Strategies

In most small island contexts, the costs of adaptation through accommodation are prohibitive so that it has in most cases not been contemplated as a widespread option. However, accommodation measures such as the raising of dwellings and key infrastructure like coastal roads above ground level have been implemented to reduce the impacts of flooding in some islands (Figure 15.7). In the most populous islands of the Tuamotu atolls, French Polynesia, where between 48 and 98% of dwellings have already experienced flooding since the 1980s, elevated houses with floors built 1.5 m above ground level are subsidised by the Government as part of Risk Prevention Plans (Magnan et al., 2018). Despite this incentive, the opposition of the local authorities and population to these plans (which also include constraining setback guidelines) considerably limited implementation, hence elevated houses only represent 7% of the total housing stock. In the Philippines (Tubigon) and Indonesia (Jakarta area) residents have elevated their houses by building stilted houses or raising the floor using coral stones to face increased flooding (Jamero et al., 2017; Esteban et al., 2020). Also, in Puerto Rico houses have been raised to address flooding (Lopez-Marrero, 2010).

In some small island settings, land reclamation (i.e., land gain through infilling) has been implemented for decades to allow for infrastructure construction and to address land shortages arising from high population growth. For example, land reclamation in Port of Spain, the capital city of Trinidad, has long been used as a solution space to meet land for housing, industrial development and infrastructure provision (Mycoo, 2018b). Likewise, one third of the land area of Male', the capital island of the Maldives, results from land reclamation (Naylor, 2015). Land reclamation is also common in Pacific atoll countries and territories, where it occurs both in urban islands facing high population pressure, such as South Tarawa, Kiribati (Biribo and Woodroffe, 2013), Funafuti Atoll, Tuvalu (Onaka et al., 2017), and Rangiroa Atoll, French Polynesia (Duvat et al., 2019b), and in rural islands, e.g., Takapoto and Mataiva atolls, French Polynesia (Duvat et al., 2017b). In some cases, land reclamation has paved the way for land raising, which is increasingly considered to adapt to SLR in small islands contexts (Figure 15.7). For example, since the 1990s, the capital area of the Maldives has been expanded through the construction of a large new island, Hulhumale', which is still under construction and is built 60 cm higher than Male' to take into account SLR (Hinkel et al., 2018; Brown et al., 2020). More generally, in the Maldives, the 2004 Indian Ocean Tsunami has boosted island raising as part of the "safe island development programme" (Shaig, 2008). Recent studies suggest that land and island raising have some potential in small islands, especially in urban high-value areas where this can generate substantial revenues through the sale or lease of new land, and therefore leverage public adaptation finance (Bisaro et al., 2019).

15.5.3 Migration

Migration, including planned resettlement, is increasingly occurring in small islands to intentionally respond to or prepare for climate change impacts (Figure 15.7; Magnan et al., 2019). There is currently *limited evidence* and *low agreement* in the literature as to whether migration of various types is an effective strategy to adapt to localised impacts of climate change, as outcomes are highly context specific (Donner, 2015; McNamara et al., 2016; Hermann and Kempf, 2017; McMichael et al., 2019; Piggott-McKellar et al., 2019a; Tabe, 2019; Bertana, 2020; Weir, 2020).

In-situ adaptation options are frequently the preference of communities over resettlement (Jamero et al., 2017) and in many documented cases, relocation – both planned and autonomous – is an adaptation option of last resort due to high economic and socio-cultural cost (McNamara and Des Combes, 2015; Jamero et al., 2017; Crichton et al., 2020). In small islands, there is *medium evidence* and *high agreement* that the degree of migrant agency and choice in decisions about whether to move, where, when and how is an important determinant of success and therefore 'adaptiveness' (see Cross-Chapter Box MIGRATE in Chapter 7; McNamara and Des Combes, 2015; Hino et al., 2017; McMichael et al., 2019; Piggott-McKellar et al., 2019a; Bertana, 2020) . Two case studies of community relocation in Fiji (Denimanu and Vunidogoloa villages) recommend that participatory inclusion of all social groups in the relocation planning process, including in planning for livelihood sustainability in new locations, should be ensured in future planned community relocation to foster positive adaptive outcomes (Piggott-McKellar et al., 2019a).

There are few examples of highly 'successful' and therefore adaptive international resettlement or relocation in response to environmental pressures in history. For example, the experiences of Gilbertese resettled in the Solomon Islands highlight that tensions with host communities over land and resource rights and limited knowledge of new environments (such as where communities previously reliant on marine resources are resettled in high island locations) can create new vulnerabilities (Donner, 2015; Weber, 2016a; Tabe, 2019). Even where gradual international relocation is supported and planned through policy as in the case of Kiribati's "migration with dignity" strategy, strong cultural connection to land and uncertainty about life in receiving communities in Australia and New Zealand means that many remain opposed to indefinite or permanent migration (Allgood and McNamara, 2017; Hermann and Kempf, 2017). The same challenges could apply where domestic migration occurs between significantly different cultural, social and physical environments. However, planned migration for employment or education can reduce exposure in sending locations and spread risk through expanding economic opportunities and providing remittances, thus having inadvertent adaptation outcomes (Campbell, 2014a). Policies which support migration for employment by the most vulnerable - those that may wish to migrate but lack the resources to do so - may offer an adaptive strategy to environmental pressure, particularly where these incorporate adequate preparedness for life in host communities (Luetz, 2017; Curtain and Dornan, 2019; Drinkall et al., 2019). Research from the Maldives suggests that women and men do not possess equal capacities to use mobility as a strategy to adapt to climate change, with women less able to employ migration as an adaptation strategy due to gender roles, social expectations, economic structures, political laws and religious doctrines, and gender norms and cultural practices (Lama, 2018).

Forced relocation, involuntary displacement and low-agency migration (for example, due to low migrant financial resources, or limited participation in migration planning) is commonly associated with unsuccessful outcomes and can therefore be considered an impact of climate change rather than an adaptation strategy (Weber, 2016a; Thomas and Benjamin, 2017; Tabe, 2019). Resettlement of households, communities and larger island populations is increasingly discussed in the context of loss and damage when in-situ adaptation limits are thought to be reached. Limited data and research relating to adaptation limits, transformational adaptation, tolerable and intolerable risk levels in small islands, and limited ability to directly attribute climate change to migration decisions (in the context of both slow onset changes and extreme events) mean that policy applications are currently limited (Thomas and Benjamin, 2018b; Handmer and Nalau, 2019; Nand and Bardsley, 2020).

15.5.4 Ecosystem-based Measures

Small islands have focused increasingly on ecosystem-based adaptation (EbA) approaches and other Nature-Based Solutions that bring benefits both for the ecosystems and communities (Figure 15.7; Giffin et al., 2020). There is *robust evidence* on implementation of EbA approaches across small islands, yet *medium agreement* on the exact benefits of these activities (Mercer et al., 2012; Doswald et al., 2014; Nalau et al., 2018a) given the difficulties in quantifying benefits and the absence of monitoring and evaluation frameworks (Doswald et al., 2014). Traditionally, EbA activities, especially at national and regional scales, have predominantly focused on restoring or conserving coastal and marine ecosystems (e.g., coral reefs, mangrove forests and seagrass meadows), with less emphasis upon the services provided by natural inland forests (Mercer et al., 2012). Incorporation of forests is however increasing, in most cases as components of ridge to reef (Figure 15.4) (or DDR) projects (*limited to medium evidence*), and is geared towards integrated watershed management to establish downstream water security, erosion control and ultimately to protect the health of coral reef ecosystems (Förster et al., 2019).

Additionally, some islands are constructing climate-smart development plans such as improved management of existing and newly established protected areas, restoration of riparian zones, urban forests/trees, sub urban and peri urban home gardens, and improved agroforestry practices towards increasing resilience to changing climate conditions, wildfires as well as decreasing food insecurity (e.g., Pedersen et al., 2016; McLeod et al., 2019). Paired terrestrial and marine protected areas have shown that forest conservation and rehabilitation yield better outcomes for coral health as forests stabilize soils and prevent erosion and sequester groundwater pollutants (*limited to medium evidence, high agreement*) (Carlson et al., 2019). The success of protected areas is however undermined by weak governance due in part to limited financial resources which undermine management and the enforcement of regulations governing activity within them (Schleicher et al., 2019).

Since the 1990s, artificial reefs have been increasingly used in small islands to support reef restoration and reduce beach erosion, especially in the Caribbean region (e.g., Dominican Republic, Antigua, Grand Cayman, Grenada) and Indian Ocean (Maldives, Mauritius) (Fabian et al., 2013; Reguero et al., 2018). They have been more or less successful in reducing the destructive impacts of extreme events, depending on their technical characteristics and the local context. For example, while it resisted the waves generated by hurricanes Georges and Mitchell in 1998, the artificial reef (Reef Ball breakwater type) implemented at Gran Dominicus Resort, Dominican Republic, did not prevent significant beach erosion. In contrast, the coral reef restoration project implemented to "build a beach" on the resort island of Ihuru, North Male' Atoll, Maldives, was successful as it allowed beach expansion and prevented the erosive impacts of the 2004 Indian Ocean Tsunami on the beach (Fabian et al., 2013).

Over the past decades, beach nourishment has been implemented in small islands either to reduce beach erosion (e.g., in tourist areas), or to protect critical human assets (e.g., roads) that are highly exposed to storm waves. It has been increasingly used to maintain beaches in the islands of the Maldives (Shaig, 2011), and in Barbados (Mycoo, 2014b). However, islands have limited sand stocks and sediment extraction can aggravate risks and/or accelerate ecosystem degradation if implemented without the necessary precautions.

In designing and implementing EbA, IKLK have high relevance especially amongst Pacific small islands as many communities are remote and still rely on ecosystems for their livelihoods (Nalau et al., 2018b; Narayan et al., 2020). In Fiji, IKLK have informed EbA projects by identifying native species suitable to strengthen the coastal environment to reduce coastal erosion and flooding in the villages (Nalau et al., 2018b). Whole-of-island approaches, like Lomanu Gau in the Gau Island in Fiji, try to foster integrated management practices in small islands that are based on shared governance of resources, and understanding the interlinkages between sectors and ecosystems (Remling and Veitayaki, 2016). In the Caribbean, EbA approaches are somewhat absent in national and regional programmes and plans, yet at the local scale EbA strategies are used increasingly with implementation mostly led by NGOs (Mercer et al., 2012).

EbA approaches have many benefits but also face several challenges and limits. Biophysical limits can make some EbA and Nature-based Solutions ineffective: coral reefs are *unlikely* to withstand increased temperatures, reducing the effectiveness of coral reef based EbA options under higher temperature scenarios (Barkdull and Harris, 2018; Cornwall et al., 2021). Likewise, many other coastal and marine ecosystems, such as mangroves, face severe limitations with increasing sea levels and other climate impacts (Morris et al., 2018; Thomas et al., 2021).

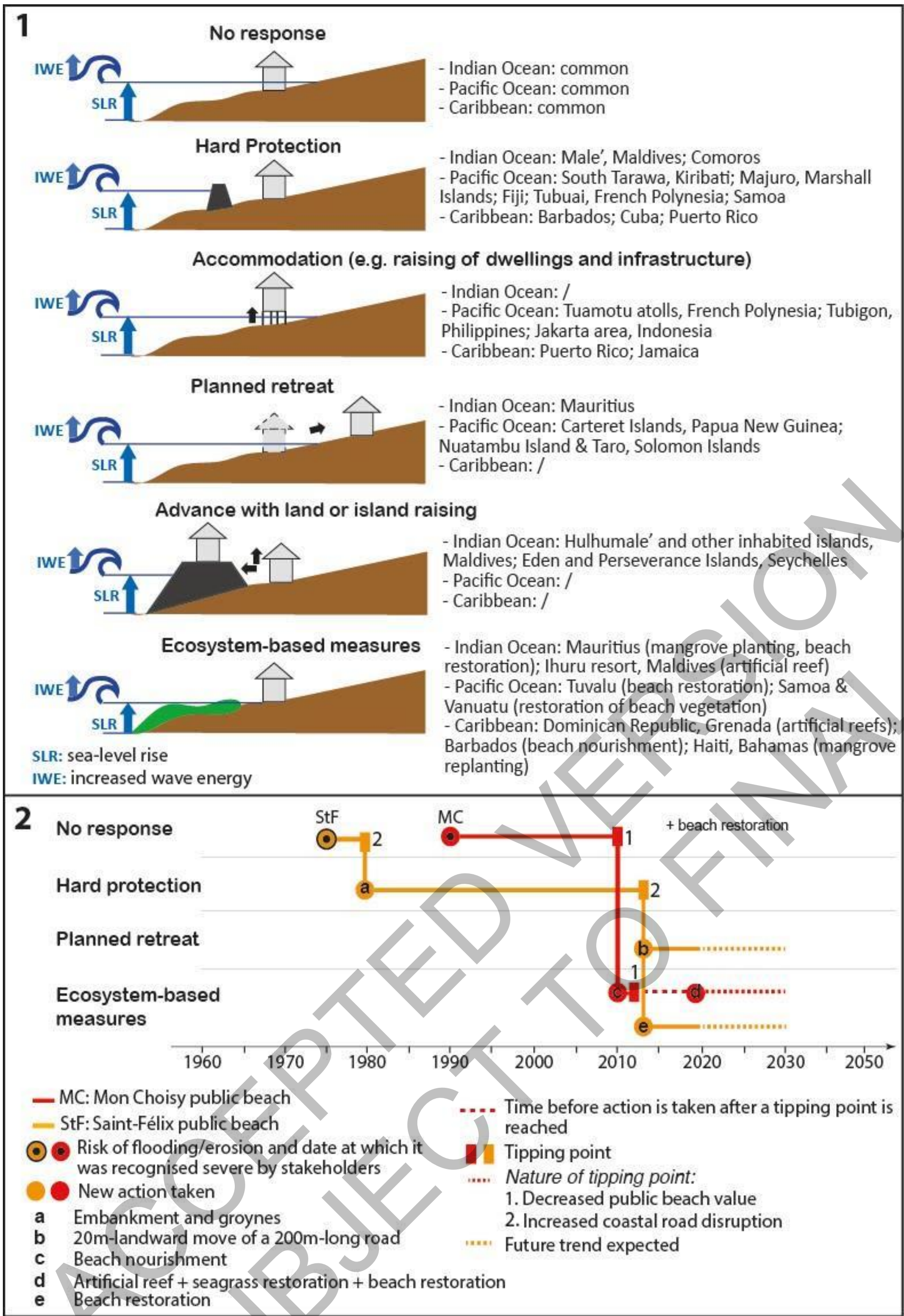


Figure 15.7: Adaptation measures implemented to reduce coastal risks in small islands. Panel 1 provides examples of implementation of different types of measures aimed at reducing coastal erosion and flooding. The measures include no response (no intervention, widespread in small islands), hard protection through the construction of engineering-based structures, accommodation through dwelling and infrastructure raising, planned retreat, advance (i.e. especially island raising) and ecosystem-based measures, in three small island regions, the Indian and Pacific Oceans and Caribbean. It highlights the prevalence of no response, hard protection and the increasing use of ecosystem-based measures. Based on the example of two beach sites in Mauritius (Mon Choisy in the north and Saint-Félix in the south), panel 2 shows that the measures used at a given coastal site evolve over time (e.g., from no response to hard protection, and then planned retreat and ecosystem-based measures) and that recent DRR (Saint-Félix) and adaptation (Mon Choisy) projects often combine several types of measures, including retreat and ecosystem-based measures (Duvat et al., 2020a). Together, panels 1 and 2 emphasize the diversity and increasing complexity of the measures implemented in small islands.

15.5.5 Community-based Adaptation

Community-based Adaptation (CBA) is best described as a "community-led process based on meaningful engagement and proactive involvement of local individuals and organisations" (Remling and Veitayaki, 2016)(p. 380). Enabling CBA projects to succeed relies on gaining a good understanding of the socio-political context within which the communities operate, including such key issues as land tenure arrangements and ownerships, gender, and decision-making processes that operate on the ground (Nunn, 2013; Buggy and McNamara, 2016; Crichton and Esteban, 2018; Delevaux et al., 2018; Nalau et al., 2018b; Parsons et al., 2018; McNamara et al., 2020; Piggott-McKellar et al., 2020).This also includes the broader and often more urgent development issues that impact on communities' wellbeing (Piggott-McKellar et al., 2020). Community-based projects demonstrate in the Pacific that communities' vulnerabilities, priorities and needs might be a better and more effective entry point for climate adaptation than framing projects solely around climate change (Remling and Veitayaki, 2016; Weir, 2020).This is supported by a recent review of 32 CBA initiatives in the Pacific where initiatives that were locally funded and implemented were more successful than those with external international funding (McNamara et al., 2020). Initiatives that integrated EbA and climate awareness raising also performed better (McNamara et al., 2020).

While CBA approaches to adaptation projects can increase community ownership and commitment to project implementation, these can also face challenges. In Pele Island, Vanuatu, implementation of CBA projects has experienced significant failures due to elite capture of project management, internal power dynamics within communities, and different priorities of communities living across the island that were supposed to be all responsible for implementing whole-of-island projects (Buggy and McNamara, 2016). Similarly, in Samoa, consultations with community leaders led to the misplacement of a revetment wall that increased flooding in the area against engineering advice (McGinn, 2020). Also, community-scale might not be always the best fit if the best scale to leverage adaptation is across catchment or whole-of-island scale (Buggy and McNamara, 2016; Remling and Veitayaki, 2016).

15.5.6 Livelihood Responses

Communities across small islands are adapting to the impacts of climate change across a range of livelihood activities. Coastal fishers have adapted by employing several activities ranging from diversification of livelihoods to changing fishing grounds and considering weather insurance (Blair and Momtaz, 2018; Lemahieu et al., 2018; Karlsson and McLean, 2020; Turner et al., 2020). In Antigua and Vanuatu, fishers have undertaken adaptation in response to increases in air and ocean temperature, increases in wind and changes in rainfall. In Antigua, adaptation strategies amongst coastal fishers have included investments in improved technologies and equipment, changing fishing grounds, and seeking better training and education (Blair and Momtaz, 2018). In Efate (Vanuatu) the majority (87%) of the fishermen used livelihood diversification as an adaptation strategy whereas 53% also searched for new fishing areas as a result of the changing conditions (Blair and Momtaz, 2018). In Southwest Madagascar, due to deteriorated reef conditions, coastal fishermen now go further offshore to catch fish or have adapted their fishing techniques, while others closer to the tourism markets, have opted for livelihood diversification (Lemahieu et al., 2018). Coastal fishers in the Dominican Republic have also diversified their livelihoods and use local knowledge in changing fishing practices and locations depending on environmental conditions (Karlsson and McLean, 2020). In the future, increased inland rainfall could for example provide new areas for inland aquaculture in the Solomon Islands as an adaptation strategy and also reduce pressure from coastal fishing (Dey et al., 2016).

In the agricultural sector in Jamaica, adaptation strategies include varying expenditure on inputs (e.g., fertilizers, chemicals, labour), diversifying cropping patterns, expanding or prioritising other cash crops (e.g., fruits and vegetables), engaging in small-scale livestock husbandry (Guido et al., 2018), and investing in irrigation technologies due to increased drought and infrequent rainfall (Popke et al., 2016). In many higher elevation islands within the Pacific, including Vanuatu and Fiji, communities continue to use to varying degrees traditional adaptive strategies designed to reduce their vulnerability to tropical cyclones. These include planting a diversity of different crops within household and communal gardens, locating gardens in different areas within their customary lands to ensure that not all crops are destroyed due to an extreme event, and the storage, and preservation of certain foodstuffs (so-called famine foods) (Campbell, 2014b; McMillen et al., 2014; Le Dé et al., 2018; Moncada and Bambrick, 2019).

Given changes in climatic conditions, in Puerto Rico women in the coffee industry are now forming their own "micro-clusters" of complementary activities, such as rebuilding of public spaces, running environmental education programmes for children, and opening new commercial enterprises (e.g., coffee shops, and food products) that do not rely on traditional coffee supply chains or government assistance (Borges-Méndez and Caron, 2019). Such alternative livelihood strategies parallel those undertaken by Pacific women working on various local-level climate change adaptation and environmental projects throughout small island nations of the Pacific. Women report testing and using adaptive strategies informed by IKLK, but which are being modified to suit the changing environmental conditions they are encountering and those projected in the future. This includes harvesting rainwater during droughts, planting native plants along coastlines to prevent erosion and flooding, developing plant nurseries, experimenting with growing salt-tolerant (taro) crops, and relocating crop cultivation inland (McLeod et al., 2018).

The tourism sector is increasingly a major source of cash-based livelihoods across small islands. Despite the high vulnerability and sensitivity of island tourism to climate change at a national scale (Scott et al., 2019), there is evidence from the South Pacific that local tourism operators' adaptive capacity is high due to socio-cultural factors. In Samoa, adaptive capacity consists of accommodation providers' social networks, resources, past experiences and understanding of environmental conditions, and remittances as a form of informal insurance (Parsons et al., 2017). The adaptive capacity of Tongan tour operators is strengthened by high climate change awareness, strong social networks and remittances as well as perceived high resilience against climate change (van der Veeken et al., 2016).

Evidence from Vanuatu shows that climate risk to tourism destinations is influenced by multiple, interconnected economic, socio-cultural, political, and environmental factors suggesting that holistic approaches are needed to reduce risk and avoid negative knock-on effects (Loehr, 2019). Tourism can strengthen mechanisms that reduce vulnerability and increase adaptive capacity of the wider destination, such as providing adaptation finance, investing in education and capacity building, and working with nature (Loehr, 2019).Examples include numerous EBA initiatives in the Caribbean including Marine Protected Areas in St. Lucia and Jamaica (Mycoo, 2018a). In Vanuatu, tourism businesses are engaged in establishing Marine Protected Areas to address multiple risks from climate change, population growth and development (Loehr et al., 2020). In the Seychelles, coral restoration programmes and mangrove reforestation are promoted through public-private partnerships, generating new opportunities for wetland-tourism livelihoods (Khan and Amelie, 2015).

The willingness of tourism businesses to finance adaptation measures varies. Islands have developed building codes which consider impacts from sea level rise but these are often not enforced enforced (Hess and Kelman, 2017). In cases where tourist resorts have been part of climate adaptation projects, such as funding for hard coastal protection infrastructure, the resort owners find that these diminish the aesthetics of the beach destination (Crichton and Esteban, 2018). Adaptation taxes and levies imposed on tourism can provide funding (Mycoo, 2018a) as The Environmental Protection and Tourism Improvement Fund Act, 2017 of British Virgin Islands shows (Smith, 2017). A lack of interaction between tourism and climate change decision makers is a commonly identified issue (Becken, 2019; Mahadew and Appadoo, 2019; Scott et al., 2019). A number of adaptation measures are recommended in the literature such as increasing climate change research, education and institutional capacities; product and market diversification away from coastal tourism to include terrestrial-based experiences and heritage tourism, and mainstreaming adaptation in tourism policies and vice versa (e.g., to include appropriate planning guidelines for tourism development, coastal setbacks and environmental impact assessments (Mycoo, 2018a; Becken et al., 2020) Thomas et al., 2020; van der Veeken et al., 2016).

15.5.7 Disaster Risk Management, Early Warning Systems and Climate Services

Disaster risk management (DRM) investments in small islands are commonly framed as reducing climate change-driven risk and contributing to sustainable development (Johnston, 2014; Mercer et al., 2014a; Kuruppu and Willie, 2015). Examples include strengthening the capacity of National Meteorological and Hydrological Services (NMHS) to deliver effective (WMO et al., 2018); nurturing community-based DRM to build social capital (Blackburn, 2014; McNaught et al., 2014; Gero et al., 2015; Handmer and Iveson, 2017; Chacowry et al., 2018; De Souza and Clarke, 2018; Currenti et al., 2019; Cvitanovic et al., 2019;

Hagedoorn et al., 2019), as well as processes that integrate IKLK with science (Hiwasaki et al., 2014; Carby, 2015; Bryant-Tokalau, 2018a; CANARI, 2019).

Many small islands, especially those with the highest risks and the least resources, remain highly challenged in building and sustaining integrated, people-centred, end-to-end early warning systems that are fully functional across the four interrelated components of EWS. Warning dissemination and communication, and disaster preparedness and response capacities are particular components of EWS requiring strengthening in SIDS (WMO, 2020). More recent assessments of early warning capabilities in the Caribbean highlight improvements in EWS for weather, water and climate over time (WMO et al., 2018; Mahon et al., 2019). However, progress has been uneven across hazards, governance levels and spatial and temporal scales, with more advanced development of some sub-systems and EWS pillars than others. Significant progress has been made in the area of detection, monitoring, analysis and forecasting of severe weather systems but there is a need to strengthen this area for other climate-related hazards such as wildfires, localised intense rainfall, floods, as well as heatwaves and droughts which become more important in a changing climate. Assessments also point to specific deficiencies including significant gaps in the area of disaster risk knowledge - particularly the development of risk assessments, the variable capacity for interpreting scientific warning products across states, as well as effective communication of warning messages to populations at risk (Lumbroso et al., 2016; WMO et al., 2018).

There is increasing recognition and commitment at global (Section 3.6.3.2.4; WMO, 2014; UN, 2015c; UN, 2015b; UN, 2015a), regional (CCCCC, 2012; CDEMA, 2014; SPC, 2016; SPREP, 2017; CIMH et al., 2019) and national levels (SPREP, 2016a; WMO, 2016a) of the importance of climate services in supporting adaptation decision making in small islands (*medium evidence, high agreement*). A number of SIDS-focused climate service programmes have emerged, especially in the Caribbean and Pacific (Group, 2015; Martin et al., 2015; SPREP, 2016b; WMO, 2016b; WMO, 2018a; WMO, 2018b) and at least one SIDS – Dominica - has been prioritised as a pilot implementation country under the Global Framework for Climate Services (WMO, 2016a). As is the case globally, climate services focused on decision-making at seasonal (3–6 month) timescales has thus far been the focus of investment in small islands. Less attention has been given to investments in and assessments of climate services for decision making at longer timescales (Vaughan et al., 2018).

Studies from the Caribbean (Dookie et al., 2019; Mahon et al., 2019) and Indian Ocean (Hermes et al., 2019), have found that NMHSs and regional intergovernmental bodies face capacity challenges in translation, transfer, and facilitation of the use of climate information to various end user groups. In many small island contexts a gap remains between investments in data quality and information services and uptake and use in risk reduction by policy and decision makers (Dookie et al., 2019). Bringing policy makers and users together to guide investments in climate information services is recommended, as is provision of dedicated resources to develop applicable tools and products that turn data and information services into risk reduction measures (Dookie et al., 2019; Haines, 2019).

Many of the outlined Key Risks (Section 15.3.4.9) can be addressed through the variety of adaptation options outlined in the previous sections in the context of small islands (Table 15.6, Supplementary Material 15.1). Whereas some of these adaptation options are widespread (e.g., hard protection, reforestation or the creation of MPAs), others (e.g. accommodation, health awareness raising and training) have been little experimented with to date in small island contexts. Although most of these adaptation options provide diversified co-benefits to small island communities, there is still *limited evidence* with regard to their effectiveness in reducing climate change impacts. While some of them respond directly to a Key Risk or a number of Key Risks (Table 15.6), others can be understood as overarching options that, for example, build adaptive capacity of communities and organizations and enable these actors to respond to a variety of Key Risks in an effective manner (see Supplementary Material 15.1).

Table 15.6: Adaptation options per Key Risk in small islands. This table summarizes risk-oriented adaptation options, their level of implementation, enablers and effectiveness in reducing exposure and vulnerability, co-benefits and disbenefits in small islands. For Key Risk 2 (submergence of reef islands), not included, adaptation options are the same as for Key Risk 5.

[INSERT TABLE 15.6 HERE]

15.6 Enablers, Limits and Barriers to Adaptation

Since AR5, more literature has emerged on barriers, limits and enablers to climate change adaptation across small islands. Here, we cover barriers, limits and enablers as they relate to key themes across small islands and adaptation.

15.6.1 Governance

Specific governance-related barriers for effective adaptation include: lack of coordination between government departments and sectors and limited policy integration (Scobie, 2016; Robinson, 2018b), lack of ownership of adaptation implementation in cases where communities or national governments have not been part of the adaptation decision process (Conway and Mustelin, 2014; Kuruppu and Willie, 2015; Prance, 2015; Nunn and Kumar, 2018; Parsons and Nalau, 2019), and difficulties in integrating IKLK in adaptation initiatives. Specific barriers to effective sustained adaptation in the Pacific include variable climate change awareness among decision-makers, and the preference for short-term responses rather than longer-term transformative ones (Nunn et al., 2014). These barriers also stem from donors' preferencing their own priorities that do not necessarily fit the country priorities or context (Conway and Mustelin, 2014; Kuruppu and Willie, 2015; Prance, 2015), which has led to increasing calls for effective community/cultural engagement in adaptation, especially through CBA and EbA (Nalau et al., 2018b). In cases where recovery efforts are framed as purely a matter of infrastructure other important aspects, such as livelihoods and gender, are more easily overlooked in adaptation (Turner et al., 2020).

In the Caribbean small islands such as Jamaica and St. Lucia, and also in the Pacific, barriers to mainstreaming adaptation include competing development priorities, the absence of planning frameworks or 'undetected' overlaps in existing frameworks, serious governance flaws linked to the prevalence of corruption and corrupt people in political and public life, and insufficient manpower and human resources, linked to countries' financial capacity (Robinson, 2018b). In addition, the lack of strong governance mechanisms for urban planning have contributed to urban sprawl and expansion that has increased the number of informal settlements, which together with population growth are driving Caribbean small islands to their limits (Enríquez-de-Salamanca, 2018; Mycoo, 2018a; Mycoo, 2018b). In the Pacific, only a few countries have embedded climate change adaptation in existing legislation despite the overall regional agreement to *A New Song for Coastal Fisheries - Pathways to Change: the Noumea Strategy*' to improve coastal fisheries management in a changing climate (Gourlie et al., 2018). Many climate change specific initiatives across small islands have a unidirectional focus on climate risks and shift limited resources away from other important development objectives (Baldacchino, 2018). Local level plans are often overlooked: for example, in Mauritius, local level climate adaptation plans are currently nearly non-existent while district councils have rarely been successful in even accessing international adaptation finance (Williams et al., 2020). In Samoa, several national level programs on adaptation have had difficulties in engaging with the local level even if the decision-making powers on actual land management sit within the communities (McGinn and Solofa, 2020).

Adaptation governance is also complicated further by the multitude of stakeholders involved, with differing agendas and priorities. In the Bahamas, private properties have significant say in how and what adaptation measures they decide to pursue and are not well regulated, with the tourism sector in particular dominated mainly by external investors (Petzold et al., 2018). Social organisations, such as the churches, that have significant influence in many Oceanic countries, are engaging in climate change discussions and governance. Many churches report, however, being constrained to act on climate adaptation due to lack of financial resources, low levels of professional knowledge on adaptation, and their members not perceiving climate change as an urgent risk (Rubow and Bird, 2016). Actors such as military services in the Indian and Pacific Oceans also control a high number of assets in vulnerable locations and will need to integrate climate information into adaptive planning in the future (Finucane and Keener, 2015).

Low technical capacity, and poor data availability and quality are reported as limiting adaptation in Caribbean small islands such as Dominica, and St. Vincent and the Grenadines (Smith and Rhiney, 2016; Robinson, 2018a) and Trinidad and Tobago (Mycoo, 2020). These factors are, however, secondary to the lack of finances, which is seen as a fundamental limit (Charan et al., 2017; Robinson, 2018a; Williams et al., 2020). This was also reported in the Seychelles, despite its success with innovative financing streams and being a leader in the Indian Ocean in this regard (Robinson, 2018a).

Limited regional cooperation across sub-national island jurisdictions (jurisdictions with semi-autonomous status) along with limited regional-scale climate information are also stymying action (Petzold and Magnan, 2019). This is a concern given the need for pooled governance in response to capacity constraints across small jurisdictions (Dornan, 2014; Kelman, 2018). There is also an insufficient understanding of the role of regional and international actors such as the Caribbean Community Climate Change Centre and the Global Environment Facility, respectively (Middelbeek et al., 2014). Sometimes external pressure and, for example, trans regional trade agreements are "useful for reducing unsustainable local socio-political arrangements" as seen in the Solomon Islands regarding fisheries management within the concept of Blue Economy (Keen et al., 2018, p. 338). Similarly, in Samoa, the World Bank's Pilot Program for Climate Resilience (PPCR) and Adaptation Fund's Enhancing Resilience of Samoa's Coastal Communities to Climate Change, illustrate successful examples of multi-level governance due to their programmatic and pragmatic approaches versus project-based approaches (McGinn and Solofa, 2020). Enabling factors in these programmes relate to strategic placements of funds and responsibilities in the relevant ministries, alignment with national priorities and pre-existing plans, pooling funding to fill existing finance gaps, and increased awareness across scales and departments of synergies and gaps between different initiatives (McGinn and Solofa, 2020). Initiatives such as the Pacific Adaptive Capacity Framework (Warrick et al., 2017) and regional strategies such as the Framework for the Disaster and Climate Resilient Development in the Pacific (FRDP) enable the localising of climate adaptation into cultural contexts in an integrated manner (SPC, 2016).

Countries including the Seychelles and Maldives have developed national climate change plans that recognize linkages to food security, health and disaster risk reduction, although these-face significant resourcing issues when it comes to implementation (Techera, 2018). National level plans, such as National Adaptation Plans of Action (NAPAs), increasingly could include local government engagement and have a stronger focus on urban centres and adaptation (Mycoo, 2018a). Building codes act as supportive enablers for adaptation governance: requiring more hurricane-resistant housing in the Caribbean, including incentives for informal settlements to build in a more resilient manner, can achieve multiple development and adaptation outcomes (Mycoo, 2018a). In Dominica, a Climate Resilience Executing Agency of Dominica (CREAD) established in 2019, aims to enable stronger climate resilience by bringing all sectors and services together for more effective coordination (Turner et al., 2020). Improvements in cross sectoral and cross agency coordination are creating opportunities for improved disaster preparedness and resilience measures in Vanuatu (Webb et al., 2015). A range of mechanisms also exists in the tourism industry: adaptation taxes and improved building regulations could reduce risk drastically for example in the Caribbean region (Mycoo, 2018a).

15.6.2 Health-Related Adaptation Strategies

The term 'health systems' refers to the organisation of people, institutions, and resources that work to protect and promote population health. The two components of health systems are public health and health care; adaptation is needed in both to develop climate-resilient health systems (WHO, 2015). Adaptation measures focus on each of the building blocks of health systems, including leadership and governance; a knowledgeable health workforce; health information systems; essential medical products and technologies; health service delivery; and financing. Many small island states have policies to manage climate-sensitive health risks, although Ministries of Health are largely unprepared to adapt to a changing climate because few programmes take climate change into account (McIver et al., 2016). Particularly vulnerable groups, such as Indigenous peoples, are often inadequately represented in adaptation planning processes and implementation, resulting in less effective interventions (Jones, 2019).

A range of climate-sensitive diseases pose threats to island communities. A vulnerability and adaptation assessment conducted in Dominica identified vector-, water- and food-borne diseases and food security as priority threats from climate change (Schnitter et al., 2019). Short-term adaptation options include strengthening solid waste management and enforcing current legislation; increasing public awareness; training health sector staff; improving the reliability and safety of water storage practices; improving climate change and health data collection methods and enhancing environmental monitoring; enhancing the integration of climate services into health decision-making; strengthening the organisational structure of emergency response; and ensuring sufficient resources and surge capacity. Longer-term adaptation options include developing early warning and response systems for climate-sensitive health risks; enhancing data collection and information flow; increasing the capacity of laboratory facilities; and developing emergency plans. For example, rainfall is the best environmental predictor of malaria in North Guadalcanal, Solomon Islands, leading to the development of an early warning tool that could increase resilience to climate change (Smith et al., 2017; Jeanne et al., 2018).

In small island states, water, sanitation, and hygiene infrastructure are particularly vulnerable to climate change, with impacts on the burden of diarrheal diseases. The resilience of types of sanitation infrastructure in urban and rural households in the Solomon Islands differ under scenarios of increased rainfall and flooding versus decreased rainfall and drought, reinforcing the centrality of taking the local context into account during adaptation decision-making (Fleming et al., 2019). Healthcare facilities, including hospitals, clinics, and community care centres, are vulnerable to extreme weather and climate events, such as flooding and TCs, and to climate-related outbreaks of infectious diseases that overwhelm their capacity to provide critical services (WHO, 2020). These facilities may lack functioning infrastructure and trained health workforce, and be predisposed to inadequate energy supplies, and water, sanitation, and waste management services. Adaptation is needed to build resilience and contribute to environmental sustainability.

Many major health care facilities in small island states are in exposed coastal areas and have limited ability to provide health services during disasters when services are most needed (WHO, 2018). For example, in Vanuatu, TC Pam in 2015 severely damaged two hospitals, 19 health care centres, and 50 healthcare dispensaries in 22 affected islands (Kim et al., 2015). A Smart Hospital Initiative in the Caribbean focuses on improving hospital resilience, strengthening structures and operations, and installing green technologies to reduce energy consumption and provide energy autonomy during extreme events and disasters (https://www.paho.org/en/health-emergencies/smart-hospitals).

15.6.3 Adaptation Finance and Risk Transfer Mechanisms

In the majority of small island developing states there is a high dependence on international financing to support adaptation to slow and rapid onset events (Robinson and Dornan, 2017; Petzold and Magnan, 2019). However, funds tend to be geared towards supporting sectoral-level adaptation initiatives for vulnerable natural resource sectors such as water, biodiversity and coastal zones (Kuruppu and Willie, 2015). Considering low income small islands such as Comoros, Haiti, and São Tomé and Príncipe, international modalities do little to address the root causes of vulnerability or to support system-wide transformations (Kuruppu and Willie, 2015). Although countries like Trinidad and Tobago have amassed oil wealth, the profits are not invested in a way that benefits environmental goals (Middelbeek et al., 2014). In Mauritius, a lack of financial resources for climate change adaptation has been recognised as a specific impediment in district council level (Williams et al., 2020).

Although small island jurisdictions have seen increased flows of adaptation finance through mostly top-town arrangements, they face large implementation difficulties (*medium evidence, high agreement*) (Weir and Pittock, 2017; Magnan and Duvat, 2018). There are growing concerns among policy- and decision-makers in small islands about the current levels and forms of adaptation finance, and about countries' experience with accessing it (Robinson and Dornan, 2017). In the Caribbean, 38% of flows were concessional loans and 62% were grants (Atteridge et al., 2017); the situation in the Atlantic and Indian Oceans is starkly different—nearly 75% of the flows were in the form of concessional loans and grants accounted for the remaining 25% (Canales et al., 2017). This raises questions about fairness and justice for small islands having to finance adaptation to climate impacts to which they have made a negligible contribution. In the Pacific, 86% of aid was delivered as project-based support (Atteridge and Canales, 2017), that can undermine the long-term sustainability of adaptation interventions (Conway and Mustelin, 2014; Remling and Veitayaki, 2016; Atteridge and Canales, 2017). Direct budget support was rare (Atteridge and Canales, 2017), signalling the importance of works such as Rambarran (2018) that support cross-regional lesson-learning by, for example, showcasing the experience of Seychelles with successfully devising innovative financing mechanisms for supporting adaptation and conservation goals, and reducing its public debt. Regional catastrophe risk insurance schemes however, such as Pacific Catastrophe Risk Insurance Company under the World Bank's Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) Program are trying to enable a regional effort in increasing accessibility to insurance (PCRAFI, 2017) as does the Caribbean Catastrophe Risk Insurance Facility, although these funds are still rather small compared to the needs across the countries (Handmer and Nalau, 2019).

Microfinance is increasingly viewed as a positive mechanism to improve access to climate adaptation funding (Di Falco and Sharma, 2018). In the Caribbean, a significant barrier in accessing climate finance relates to bureaucratic structures, which means that money intended for communities does not reach them (Mycoo, 2018a). Many adaptation projects even at the community level have upfront costs that need to be supported, especially in communities where there is little hard cash in use (Remling and Veitayaki, 2016). Despite such challenges, communities in the Pacific region have used "cashless adaptation" for a long time that involves trading of services and items as a form of Indigenous microfinance (Nunn and Kumar, 2019b). Social networks also function as a source of informal microfinance where extended family members send back remittances from overseas to their families and communities especially after disasters. In Samoa Indigenous tourism operators receive remittances from overseas family members (Crichton and Esteban, 2018; Parsons et al., 2018), with similar processes observed among atoll communities in the Solomon Islands (Birk and Rasmussen, 2014), Vanuatu (Handmer and Nalau, 2019) and Jamaica (Carby, 2017). However, the role of migration and remittances is still poorly understood; it is difficult to quantify the informal flows and understand the extent they support effective adaptation (*limited evidence, high agreement)* (Campbell, 2014a; Parsons et al., 2018; Handmer and Nalau, 2019).

In Old Harbour Bay, Jamaica's largest fishing village, a high number of community members engaged in the fishing industry, particularly vendors and scalers, do not own the material assets needed to fully benefit from these livelihood activities (Baptiste and Kinlocke, 2016). Developing a broader asset portfolio by increasing access to such assets via adaptation finance investments could reduce vulnerability across the community. This could function as an effective livelihood-based adaptation strategy for the most vulnerable such as women, who are part-time employed and in peripheral roles in the fishing industry (Baptiste and Kinlocke, 2016). In Belize and the Dominican Republic, many coastal fishers for example use informal credit from food stores or captains to enable them to withstand financial losses that are often incurred during bad weather and extreme events (Karlsson and McLean, 2020).

In Vanuatu, discussions are ongoing on increasing insurance availability for TCs and droughts, but standardisation of housing designs to get insurance can become difficult where the costs make it prohibitive and run counter to traditional building designs and materials (Baarsch and Kelman, 2016). Empirical evidence from Belize, Grenada, Jamaica and St. Lucia indicates that there are also other factors why people do not take insurance, including "the cost of premiums (44 %), lack of trust in insurance companies (27 %), having never considered insurance (26 %), a lack of need for insurance (25 %) and a lack of knowledge of insurance (22 %)" (Lashley and Warner, 2013, p. 108). Increasing trust could be addressed by seeking out domestic banks or credit unions with whom people are already engaging with, while also using social marketing campaigns to raise awareness of weather-related insurance to address knowledge gaps and lack of awareness of these tools (Lashley and Warner, 2013). In Dominica, many coastal fishers are suspicious of insurance schemes given past experiences of not being paid out on time or having to disclose catch data (Turner et al., 2020). Yet, insurance is not capable of addressing all kinds of loss and damage accruing from climate impacts and should be used as an adaptation strategy in combination with other strategies (Lashley and Warner, 2013).

Insurance cover is a critical question in small islands. For example, in Vanuatu, some companies do not "cover storm damage from the sea or high tides…which is not helpful for properties damaged by a tropical cyclone's storm surge" (Baarsch and Kelman, 2016)(p. 6). There is also limited access to insurance schemes due to lower demand in small markets (Petzold and Magnan, 2019) especially when many people do not have high cash-based incomes and likely cannot pay insurance premiums (Baarsch and Kelman, 2016). In Saint Lucia and Grenada (via the Caribbean Oceans and Aquaculture Sustainability Facility), discussions are ongoing with regard to national level parametric insurance, underpinned by financing from the US State Department, to help fishing communities recover more quickly following the passage of TCs in the future (Sainsbury et al., 2019; Turner et al., 2020). Likewise, (Reguero et al., 2020) have suggested a resilience insurance mechanism that could in theory reduce climate related losses and damages through investments in nature-based adaptation projects (e.g. coral reef restoration and potentially mangrove restoration).

15.6.4 Education and Awareness-Raising

A significant barrier to effective climate adaptation is the lack of education and awareness around climate change both among the general public, for example in the Bahamas (Petzold et al., 2018) and among decision-makers in the more remote rural communities (Nunn, 2013; Mycoo, 2015). Increasing knowledge on adaptation options and needs can increase adaptive capacity that is underpinned by "the ability of individuals to access, understand and apply the knowledge needed to inform their decision-making processes" (Cvitanovic et al., 2016 p. 54). This should however also be seen as a collective effort (Hayward et al., 2019).

Workshops and training are seen as crucial at the local scale to build communities' capacity to take action and to integrate climate change considerations to the broader development processes (Remling and Veitayaki, 2016), although purely workshop-based short-term capacity building in adaptation has been questioned (Conway and Mustelin, 2014; Lubell and Niles, 2019). More interactive community engagement strategies could include "participatory three-Dimensional modelling (P3DM), participatory video, development of photo journals, and civil society plans" (Beckford, 2018, p. 46) that enables broader engagement. In Fiji, Laje Rotuma youth EcoCamps have been used to engage younger Fijians to understand adaptation and increasing environmental stewardship with good outcomes (McNaught et al., 2014). In Palau, Camp Ebiil provides a culturally-based platform for younger generations to learn about nature and culture in an interactive camp (Singeo, 2011). Vanuatu's Volunteer Rainfall Observer Network in turn engages volunteers to record their rainfall observations, demonstrating the use of IKLK that can be integrated with contemporary weather forecasting (Chand et al., 2014). Likewise, initiatives such as ePOP Petites Ondes Participatives aim to develop a citizen network to share environmental information (e.g., via minivideos on smartphones). Across the Pacific, projects such as the European Union Pacific Technical Vocational Education and Training on Sustainable Energy and Climate Change Adaptation Project (EU PacTVET), have sought to increase capacity of Pacific islanders in disaster risk management and climate adaptation (Hemstock et al., 2018).

In Fiji, a study on adaptive behaviour and intention to invest in more adaptive portfolios found that the intent for adaptive behaviour increased with the supply of climate information (Di Falco and Sharma, 2018). In the Pacific, high performing CBA initiatives included climate awareness raising that equipped people with knowledge to understand occurring environmental changes and what to do (McNamara et al., 2020). Lack of information can increase community vulnerability. Remote Indigenous farming communities in St Vincent, in the Caribbean, for example have already observed decreased rainfall and increases in temperatures, but they have been largely excluded from agricultural training that includes information in how to improve agricultural strategies in times of climatic shocks and how to prepare for changing climatic conditions (Smith and Rhiney, 2016). In the Bahamas, cultural background, income and education levels impact the extent that people are aware of climate risks (Petzold et al., 2018) . In Dominica, access to information critical to fisheries is noted as a significant challenge, including data collection, its management and human resources in building capacity to process and use this information for evidence-based decision making (Turner et al., 2020).

The Caribbean Climate Online Risk and Adaptation tool has been developed to assist the tourism industry in producing "climate-sensitive developments" (Mackay and Spencer, 2017,p. 55). Though some authors conclude on the low climate awareness/understanding among small islanders (Middelbeek et al., 2014; Betzold, 2015; Petzold et al., 2018), others indicate that many Caribbean islanders are acutely aware of past storm events (i.e., social memory) and have a certain degree of self-reliance, which creates the capability to multi-task and cope with limited resources (Petzold and Magnan, 2019). There is, however, a disconnect between knowledge, attitudes and practices—knowledge sharing and learning need to be improved along with the take-up of an evidence-based decision-making approach (Lashley and Warner, 2013; Petzold et al., 2018; Saxena et al., 2018).

15.6.5 Culture

Culture can be defined as "material and non-material symbols that express collective meaning" (Adger et al., 2014, p. 762) and includes worldviews and values, how individuals and communities relate to their environment, and what they perceive to be at risk and in need of adaptation (McNaught et al., 2014; Nunn et al., 2014; Remling and Veitayaki, 2016; Nunn et al., 2017bGranderson, 2017; Neef et al., 2018; Oakes, 2019). In small islands, culture plays an important role in individual and community decision-making on adaptation both as an enabling factor and as a barrier (*robust evidence, high agreement*) (Nunn et al., 2017b; Parsons et al., 2017; Neef et al., 2018; Piggott-McKellar et al., 2020). The concept of *Vai Nui* as the interconnectedness of Pacific Islanders continues to support the collective agency to plan and undertake adaptation efforts in the region (Hayward et al., 2019). In Samoa, the principles of *Fa'asamoa* (the Samoan way of life) impacts on how decisions are made, including the role of the *aiga* (extended family) that is a web of local, national and transnational kinship networks (Parsons et al., 2018). Traditional village council structures and land stewardship enables an expanded range of coastal adaptation options in Samoa, including potential relocation, but at the same time may limit participation of all social groups in adaptation decision making (Crichton et al., 2020). In Dominica, in the aftermath of Hurricane Maria (2017), social capital in the form of transboundary nearby island networks enabled some communities to recover faster from the disaster including access to more livelihood opportunities and assets (Turner et al., 2020).

Yet, culture is often overlooked in adaptation policies and plans. For example, in the National Communications of 16 SIDS, only one country (Cook Islands) reported adaptation actions that addressed social issues, culture, and heritage (Robinson, 2018b). Externally-driven adaptation efforts in rural small-island communities that exclude community priorities, ignore or undervalue IKLK, and are based on secular western/global worldviews (Donner and Webber, 2014; Prance, 2015; McNamara et al., 2016; Nunn et al., 2017b; Schwebel, 2017; Mallin, 2018; Nunn and McNamara, 2019; Piggott-McKellar et al., 2019b) are often less successful (*high agreement, medium evidence*). The World Bank Kiribati Adaptation Program (KAP) for example builds mainly on western knowledge and science despite consultations with the Kiribati communities (Prance, 2015). Yet, in many contexts most land and knowledge is embedded in traditional governance and culture while adaptation plans and decisions are made elsewhere on how that land should be used and what knowledge is used (*high agreement*) (Nunn, 2013; Prance, 2015; Charan et al., 2017; Nalau et al., 2018a; Parsons et al., 2018; McGinn and Solofa, 2020).

In Kiribati, communities often use different timescales to evaluate the need for adaptation. I-Kiribati culture's core concept of time is short- and medium term (Prance, 2015), which should be considered in adaptation policy and planning processes especially at the household and community level (Donner and Webber, 2014). Key stakeholders, especially community leaders, should be included and empowered to help design and sustain adaptation (Baldacchino, 2018; Weiler et al., 2018). Focusing on values-as-relations (e.g., island communities' relationship with the environment and each other) could diversify the values considered in adaptation decision-making processes (Parsons and Nalau, 2019). Indeed, those Pacific islands with a more island-centric approach to climate adaptation tend to have overall more successful adaptation policies in place (Schwebel, 2017).

The cultural context and sources of knowledge are myriad and diverse in small islands. Community members often use both IKLK as well as western scientific-based weather forecasts to take actions to prepare for extreme weather events (Chand et al., 2014; Johnston, 2015; Janif et al., 2016; Granderson, 2017; Kelman et al., 2017), with specific examples from Niue, Tonga, Vanuatu and the Solomon Islands *(high agreement, high evidence)* (Chand et al., 2014; Chambers et al., 2017; Chambers et al., 2019). In Samoa, people keep particular areas reserved for disaster times such as TC seasons (Kuruppu and Willie, 2015) while in Vanuatu IKLK indicators for tropical cyclones include mango trees flowering early and turtles going further inland to lay their eggs (Chand et al., 2014). IKLK are however not evenly distributed within communities due to IKLK being traditional intellectual property of particular roles in the villages (e.g., weathermen in Vanuatu), and not available to other community members or external actors directly (Chand et al., 2014; Prance, 2015). In Tongoa Island, Vanuatu, communities are finding however that their IKLK-based seasonal calendars are out of sync given the changes in climatic conditions (Granderson, 2017) while erosion of IKLK remains a concern across most small island nations (Kuruppu and Willie, 2015; Granderson, 2017; Beckford, 2018).

Not all IKLK and other knowledge are necessarily helpful and IKLK can lead to maladaptation (Mercer et al., 2012; Beckford, 2018). Elders from the Chuuk State (Federated States of Micronesia, (Elders from Atafu Atoll, 2012), for instance, assign blame for changeable weather patterns, destructive typhoons, and loss of biodiversity to people's failure to maintain and employ their IKLK. Fatalism (belief that disasters are God's will) is still reported as a major cultural barrier to adaptation. In Maldives fatalism decreases direct adaptation action and influences perceptions of climate risks (Shakeela and Becken, 2015) while Indigenous communities in St Vincent do not prepare for hurricanes or climatic shocks for the same reason (Smith and Rhiney, 2016). In Oceania, Christianity and the church play an important role in how issues, such as climate change, are communicated and thought about (Rubow and Bird, 2016; Nunn et al., 2017b), including the Noah and flood story used as a justification that there is no need to worry about sea level rise (Rubow and Bird, 2016). New emerging forms of eco-theology (theology that connects humans with land, sea and sky) however situate climate change as part of environmental stewardship (Rubow and Bird, 2016) making churches active partners in caring for the environment.

Many studies also now demonstrate the value in considering multiple systems of knowledge through collaborative and co-production projects and strategies, which allow for culturally-situated knowledge, values, and practices to be positioned at the heart of sustainable climate change adaptation *(high agreement)* (Chambers et al., 2017; Plotz et al., 2017; Beckford, 2018; Malsale et al., 2018; Parsons et al., 2018; Suliman et al., 2019). In the Caribbean context, Beckford (2018) suggests the establishment of Caribbean Local and Traditional Knowledge Network, a shared regional platform makes IKLK more available for climate adaptation and community resilience projects where appropriate. Likewise, Indigenous research methodologies are emerging that introduce more culturally grounded concepts and methods into how research is conducted and decolonise mainstream research in the Pacific Islands (Suaalii-Sauni and Fulu-Aiolupotea, 2014).

Despite widespread international evidence that the impacts of climate change and disaster events often negatively affect women (and gender minorities) more than men (McSherry et al., 2014; Aipira et al., 2017; Gaillard et al., 2017), attention to gender equality as a concept is still only "embryonic in climate change adaptation in the Pacific" and although recognised in some policies and project designs, it is not well supported by on-the-ground actions or well monitored (Aipira et al., 2017, p. 237). Many Pacific small island climate change adaptation policies do not mainstream gender across the activities (Aipira et al., 2017), with women's groups being excluded from climate grants due to patriarchal formal and informal governance structures, lack of resources, lower access to educational and training schemes, and no track record (or receiving grants or meeting grant milestones) (McLeod et al., 2018). However, Pacific women identify several strategies that enable them to adapt to climate change more effectively. These include the recognition and support of women's IKLK by governments, researchers, and NGOs; increasing women's access to climate change funding and support from organisations to allow them to meet the requirements of international climate change grants; and specific education and training to women's groups to allow them to develop strategic action plans, mission statements, learn financial reporting requirements, as well as general leadership and institutional training (McLeod et al., 2018). Such and other measures could enable a broader representation and participation in adaptation processes despite cultural constraints (Table 15.7 on Enabling Conditions).

Table 15.7: Enabling Conditions and Factors for Adaptation in Small Islands
[INSERT TABLE 15.7 HERE]

15.7 Climate Resilient Development Pathways and Future Solutions in Small Islands

Synergies exist between climate resilient development pathways and implementation of SDGs in small islands because development decisions and outcomes are strengthened by consideration of climate and disaster risk (Robinson, 2017b; Hay et al., 2019a). However, monitoring progress of SDGs is challenging for small islands, in part due to large numbers of indicators and inadequate data. Literature on SDG implementation is generally lacking for small islands as is the integration of climate risk into infrastructure decisions.

Decisions that are optimal for adaptation may not be acceptable in the wider development context within which they operate. In the Pacific region, where 67% of infrastructure is located within 500 metres of coastline and commercial, public and industrial infrastructure are particularly vulnerable due to the location of urban centres (Kumar and Taylor, 2015). Yet the Parliamentary Complex in Samoa was redeveloped at the original site due to cultural and historical factors despite strong evidence of the need to relocate (Hay et al., 2019b).

Energy transitions in the Pacific islands demonstrate development synergies such as reduced dependency on volatile fossil fuel markets, increased resilience to weather related disasters and less need for investment in large scale centralised energy systems (Dornan, 2014; Cole and Banks, 2017; Weir, 2018; Weir and Kumar, 2020). However, high and rapid energy transition ambitions can lead to trade offs for rural electrification (Box 18.4; Dornan, 2014; Cole and Banks, 2017; Hills et al., 2018).

Tourism system transitions can enable the sector to contribute to climate resilient development pathways through managing climate risks and improving ecological, economic and social outcomes for small islands (*medium evidence, high agreement*) (Loehr, 2019; Mahadew and Appadoo, 2019; Loehr et al., 2020; Sheller, 2020).

There is a clear role for local governments to work closely with the informal private sector to achieve a 'trifecta' of climate change adaptation, economic development and disaster risk reduction, especially for women (McNamara et al., 2020). Yet, many cities and local governments in the Pacific region are severely resource constrained (Kelman, 2014; Kiddle et al., 2017; Keen and Connell, 2019; Nunn and McNamara, 2019).

Broader innovation in climate resilient development policy making has taken place in the Pacific (Hay et al., 2019a) and Caribbean (Mycoo, 2018a). The Pacific region is bringing together disaster risk management, low carbon growth and climate change adaptation with broader development efforts for the first time (SPC, 2016). Improvements in cross sectoral and cross agency coordination are creating opportunities for improved disaster preparedness and resilience measures in small islands (Webb et al., 2015; Nalau et al., 2016). Further integration between development priorities and risk management in national budgetary and development processes is necessary, as is continued investment in coordination mechanisms (Hay et al., 2019a).

Early research on the response to COVID-19 indicates that existing disaster response mechanisms in the Caribbean islands have assisted in rapid responses to COVID-19 (Hambleton et al., 2020). Many small islands are highly dependent on tourism for their economies and are facing worsening crises associated with climate-related disasters and more recently COVID-19 disruptions of travel (Sheller, 2020). The adaptive capacity and innovations demonstrated by SIDS during COVID-19, moving beyond dependence on ‘extractive’ international tourism, demonstrate the potential benefits of diversified and sustainable economies (and ecologies) for the enhanced resilience of both human and ecological communities (Sheller, 2020).

In the context of small islands, climate justice research is expanding beyond initial debates about nation-states responsibilities for the causes and responses to climate change, to demonstrate complex and dynamic intergenerational and multiscalar dilemmas of climate justice (Ferdinand, 2018; Sheller, 2018; Baptiste and Devonish, 2019; Look et al., 2019; Douglass and Cooper, 2020; Kotsinas, 2020; Sheller, 2020). In Caribbean SIDS, research highlights how intersecting external and internal socio-economic and political processes are allowing marginalised populations to become increasingly socially and economically disadvantaged and politically marginalised, which in turn heightens climate vulnerability and impedes sustainable development efforts (Baptiste and Devonish, 2019) (Moulton and Machado, 2019; Gahman and Thongs, 2020; Rhiney, 2020; Duvat et al., 2021b). Inequity extends to how development and disaster aid were coordinated and distributed within various nations after Hurricanes Irma, Maria and Harvey in 2017.

15.8 Research Gaps

Despite intensive study many knowledge gaps remain due to the complexity of biophysical and social interactions, and the local and regional diversity of small islands. Research and data gaps exist in four areas: island-scale data availability; ecosystem services data; vulnerability and resilience, and adaptation (Table 15.8).

Table 15.8: Research Gaps in Small Islands
[INSERT TABLE 15.8 HERE]

[START FAQ15.1 HERE]

FAQ 15.1: How is climate change affecting nature and human life on small islands, and will further climate change result in some small islands becoming uninhabitable for humans in the near future?

Climate change has already affected and will increasingly affect biodiversity, nature's benefits for people, settlements, infrastructure, livelihoods and economies on small islands. In the absence of ambitious human intervention to reduce emissions, climate change impacts are likely to make some small islands uninhabitable in the second part of the 21st century. By protecting and restoring nature in and around small islands as well as implementing anticipatory adaptation responses, humans can help reduce future risks to ecosystems and human lives on most small islands.

Observed changes – including increases in air and ocean temperatures, increases in storm surges, heavy rainfall events, and possibly more intense tropical cyclones - are already reducing the number and quality of ecosystem services, thereby causing the disruption of human livelihoods, damage to buildings and infrastructure, and loss of economic activities and cultural heritage on small islands. Widespread observed impacts include severe coral reef bleaching events, such as that associated with the 2015–16 El Niño season, the most damaging on record worldwide. Additionally, the 2017 Atlantic hurricane season was unusually characterised by sequential severe tropical cyclones that resulted in widespread cyclone-induced damage to ecosystems from the very interior of small islands to those of the ocean waters that surround them as well as damage to human settlements and economic activities within the whole Caribbean region. Although knowledge is limited regarding long term increases in tropical cyclone intensity, studies have shown that heavy rainfall and intense wind speed of individual tropical cyclones were increased by climate change. The combination of various climate events, such as tropical cyclones, extreme ocean waves, and El Niño or La Niña phases, with sea-level rise causes increased coastal flooding, especially on low-lying atoll islands of the Indian and Pacific Oceans.

The expected increased risk of such impacts under further climate change is significant. For example, some low-lying islands and areas may be extensively flooded at every high tide or during storms. As a result, their freshwater supplies and soils would be repeatedly contaminated by saltwater, with adverse cascading consequences for freshwater and terrestrial food supplies, biodiversity and ecosystems, and economic activities. It is unlikely that these locations would remain habitable unless such impacts are mitigated through reduction of heat-trapping greenhouse gas emissions or adaptation solutions that are acceptable for the populations of these islands. Acceptable adaptation options may be limited in these locations. Additionally, drought intensity may challenge freshwater security in some regions such as the Caribbean. Likewise, remote atoll islands where inhabitants rely on reef-derived food and other resources and that are at high risk of widespread coral reef degradation may become uninhabitable. Strategies to reduce risk may include substituting the consumption of vulnerable inshore reef resources by developing onshore aquaculture (fish farming), or promoting access to tuna and other pelagic fish, and/or importing food to meet nutritional needs. However, adoption of these strategies will depend on the acceptance of their local populations.

The intensity and timing of such impacts will be more severe under high warming futures compared to low warming futures accompanied by ambitious adaptation. Tailored, desirable and locally owned adaptation responses that incorporate both short- and long-term time horizons would certainly help to reduce future risks to nature and human life in small islands. Among the short-term measures frequently employed to address sea-level rise and flooding are seawalls. Long-term measures include ecosystem-based adaptation such as mangrove replanting, relocation of coastal villages to upland sites, creation of elevated land through reclamation, revised building codes as part of a broader disaster risk reduction strategy, shifting to alternative livelihoods and changes in farming and fishing practices.

[END FAQ15.1 HERE]

[START FAQ15.2 HERE]

FAQ 15.2: How have some small-island communities already adapted to climate change?

Faced with rising sea levels and storm surges along their coastal areas which have significantly threatened people's safety, buildings, infrastructure and livelihoods, Small Island communities have already embarked on the use of different adaptation strategies. These include reactive adaptation, which deals with short-term measures, and anticipatory adaptation, which takes action in advance to lessen climate change impacts in the long run. Reactive measures have proven not always to be effective. In contrast, anticipatory measures hold much promise for future adaptation.

The majority of people living on small islands occupy coasts, so the most widespread threats to people's livelihoods are those from sea-level rise, shoreline erosion, increased lowland flooding, and salinization of groundwater and soil. Humans can either adapt reactively or anticipate coming changes and prepare for them. Given the diversity of small islands across the world, and their capacities to adapt, there is no single solution that fits all contexts.

Coastal livelihoods in particular are already impacted by climate impacts. Coastal fishers have adapted to these changes in environmental conditions by diversifying livelihoods, expanding aquaculture production, considering weather insurance, building social networks to cope with reduced catches and availability during extreme storms, switching fishing grounds, and changing target species. Similarly, farmers have diversified livelihoods to more cash- and service-based activities such as tourism, changed plant species that thrive better in altered conditions, and shifted planting seasons according to changes in climate.

A typical reactive adaptation along small-island coasts involves the construction of hard impermeable structures such as seawalls to stop the encroachment of the sea. Yet such structures, especially along rural island coasts, often fail to prevent flooding during extreme sea levels or extreme-wave impacts, and can inadvertently damage nearshore ecosystems such as mangroves and beaches. In the Caribbean, Indian Ocean islands and some Pacific islands, there are numerous examples of coastal engineering structures that have been destroyed already or are in grave danger from the encroaching sea. In many instances, citizens and governments are unable to access external advice or funding, communities have built such structures without assistance or knowledge of expected future sea level rise.

In contrast, anticipatory adaptation, which anticipates expected future impacts and acts in advance, requires a longer-term view as well as some understanding of future climate-change impacts in particular contexts. Along small-island coasts, anticipatory adaptation typically involves recognising that sea level will continue rising and that problems currently experienced will be amplified in the future. One strategy for anticipatory adaptation in response to sea level rise and flooding is relocation, which is the movement of coastal communities away from vulnerable (coastal-fringe) locations to sites that are further inland. . Coastal setback policies have been applied to hotels in some islands such as Barbados. In coastal locations where the risks of rising sea level, flooding and erosion are very high and cannot effectively be reduced, 'retreat' from the shoreline is the only way to eliminate or reduce such risks.

Where relocation is successful, it is most commonly driven and funded by governments and non-government organisations, often within a specially designed policy framework. The Government of Fiji, for example, has introduced a relocation framework that specifically develops guidance on relocation processes, with several villages already having relocated. Evaluations to date recommend thorough cost-benefit analyses of relocation be undertaken before this strategy is pursued. Relocation is often viewed as a 'last resort' adaptation option because of high cost and because some socio-cultural aspects of life cannot be maintained in locations separated from customary land. The Bahamas relocated a community on Family Island from the shoreline to an inland location and the community of Boca de Cachón in the Dominican Republic was relocated to higher ground. The Navunievu community (Bua, Fiji) has mandated that every young adult building their family home in the village should do so upslope rather than on the regularly flooded coastal flat where the existing village is located. Over the next few decades, this will result in the gradual upslope migration of the community, an example of autonomous adaptation. Such creative community-grounded solutions hold great promise for future adaptation on small islands, where they are undertaken inclusively.

Anticipatory adaptation has been aligned with disaster risk reduction in some small islands. For example, Jamaica adopted such an approach in relocating three communities. Recognising that a proactive approach is needed, Jamaica developed a Resettlement Policy Framework aligned with the National Development Plan and based on vulnerability assessments of communities at risk of climate change and disaster risk. A resettlement action plan was developed for the Harbour Heights community using community engagement to design successful planned relocation. In some islands revised building codes are implemented as an anticipatory adaptation measure. As part of the build-back-better strategy hurricane resistant roofs are being built to cope with strong winds associated with tropical cyclones.

Ecosystem-based adaptation can be a low-cost anticipatory adaptation measure that is often used in small islands. It is referred to as a ‘no-regret’ or ‘low-regret’ strategy because it is low-costing, brings co-benefits and requires less maintenance in contrast to hard engineering structures. Ecosystem-based adaptation is used at different scales and in different sectors such as to protect fisheries, farming and tourism assets, and integrates various stakeholders from national to local governments and non-governmental agencies. Many islands have implemented ecosystem-based adaptation such as watershed management, mangrove replanting and other nature-based solutions to strengthen coastal foreshore areas that are subjected to coastal erosion and flooding caused by sea level rise and changing rainfall patterns. For example, mangroves have been planted on several cays in Belize and pandanus trees have been planted near the coastlines of the Marshall Islands. Agroforestry is another example of ecosystem-based adaptation. Planting trees and shrubs in combination with crops has been used to increase resilience of crops to droughts or excessive rainfall run-off. Case studies show that people living on islands benefit even further from using ecosystem-based adaptation. Their health improves as well as their food and water supply, while risks of disasters caused by extreme events are reduced.

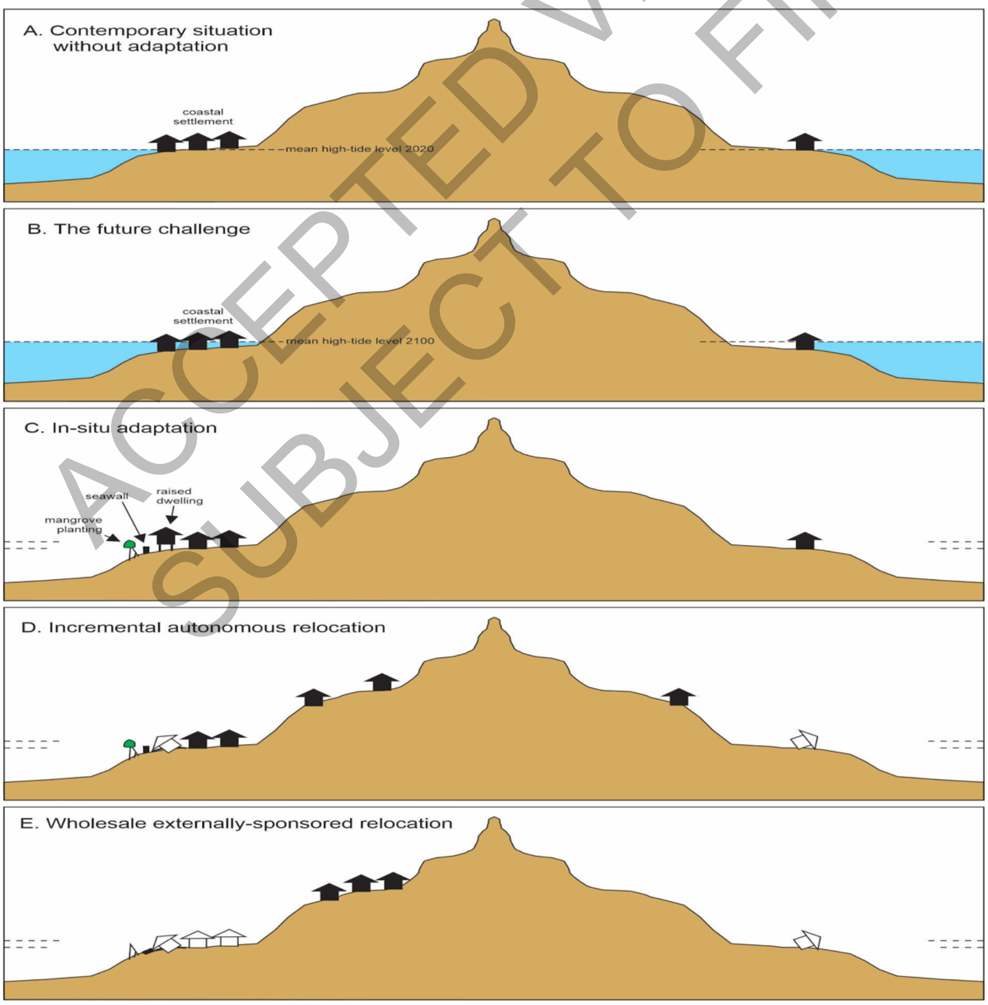


Figure FAQ15.2.1: Adaptation options for rural coastal communities in small islands
A – In many places today, coastal communities which have been established for hundreds of years are being more regularly inundated than ever before as a result of rising sea level. B – By the end of this century, sea level in such places may have risen one meter or more, making many such settlements (largely) uninhabitable, underscoring the need for effective (anticipatory) adaptation. C – One option is in-situ adaptation, popular because it is cheaper and less disruptive than other options; it is typically characterised by mangrove replanting, seawall construction and raising of dwellings. D – A second option is for communities to incrementally relocate upslope by building all new houses further inland. E – A third option is complete relocation of a vulnerable coastal community with external support upslope and inland.

[END FAQ15.2 HERE]

[START FAQ15.3 HERE]

FAQ 15.3: How will climate related changes affect the contributions of agriculture and fisheries to food security in small islands?

Agriculture and fisheries are heavily influenced by climate, which means a change in occurrence of tropical cyclones, air temperature, ocean temperature and/or rainfall can have considerable impacts on the production and availability of crops and seafood and therefore the health and welfare of island inhabitants. Projected impacts of climate change on agriculture and fisheries in some cases will enhance productivity, but in many cases could undermine food production, greatly exacerbating food insecurity challenges for human populations in small islands (also see Cross-Chapter Box MOVING PLATE in Chapter 5).

Small islands mostly depend on rain-fed agriculture, which is likely to be affected in various ways by climate change, including loss of agricultural land through floods and droughts, and contamination of freshwater and soil through salt-water intrusion, warming temperatures leading to stresses of crops, and extreme events such as cyclones. In some islands, crops that have been traditionally part of people's diet can no longer be cultivated due to such changes. For example, severe rainfall during planting seasons can damage seedlings, reduce growth and provide conditions that promote plant pests and diseases.

Changes in the frequency and severity of tropical cyclones or droughts will pose challenges for many islands. For example, more pronounced dry seasons, warmer temperatures, greater evaporation could cause plant stress reducing productivity and harvests. The impacts of drought may hinder insects and animals from pollinating crops, trees and other vegetative food sources on tropical islands. For instance, many agroforestry crops are completely dependent on insect pollination, and it is, therefore, important to monitor and recognize how climate change is affecting the number and productivity of these insects. Coastal agroforest systems in small islands are important to national food security but rely on biodiversity (e.g., insects for pollination services). Biodiversity loss from traditional agroecosystems has been identified as one of the most serious threats to food and livelihood security in islands. Ecosystem-based adaptation practices and diversification of crop varieties are possible solutions.

The continuous reduction of soil fertility as well as increasing incidences of pests, diseases, and invasive species contribute to the growing vulnerability of the agricultural systems on small islands. Higher temperatures could increase the presence of food or water borne diseases and the challenge of managing food safety. Changes in weather patterns can also disrupt food transportation and distribution systems on islands where indigenous communities are often located in remote areas.

Impacts of climate change on fisheries in small islands result from ocean temperature change, sea-level rise, extreme weather patterns such as cyclones, reducing ocean oxygen concentrations and ocean acidification. These combined pressures are leading to the widespread loss or damage to marine habitats such as coral reefs but also mangroves and seagrass beds and consequently of important fish species that depend on these habitats and are crucial both to the food security (a high proportion of dietary protein is derived from seafood) and incomes of island communities. Shifting ocean currents and warming waters are also changing the distribution of pelagic fish stocks, especially of open-water tuna, with further consequences for both local food security and national economies, where they are often highly dependent on income from fishing licenses (e.g., 98% of Gross Domestic Product in Tokelau, 66% of national income in Kiribati).

Climate change is projected to have profound effects on the future status and distribution of coastal and oceanic habitats, and consequently of the fish and invertebrates they support. High water temperature causes changes in the growth rate of fish species as well as the timing of spawning and migration patterns, with consequences for fisheries catch potential. Some small island countries and territories are projected to experience more than 50% declines in fishery catches by 2100. Other small islands such as Easter Island (Chile), Pitcairn Islands (UK), Bermuda, and Cabo Verde may actually witness increases in catch potential under certain climate scenarios. Food shortages are often apparent in small islands, following the passage of catastrophic tropical cyclones. Access to pelagic fisheries can help to alleviate immediate food insecurity pressures in some circumstances, whereas aquaculture (fish farming) is being viewed as a longer term means of diversifying incomes and enhancing resilience in many Caribbean and Pacific islands.

[END FAQ15.3 HERE]

Large Tables

Table 15.2: A small subset of projected changes in basic climate metric. Med=Mediterranean; NC=no change

Phenomenon	Location	General Trend	Metric	Specific projections 2040-2060		Specific projections 2080-2100		Comments	Reference
				RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5		
Air Temperature	Caribbean	Hotter, especially in the East	Monthly mean temperature compared to 1971-2000	NA	1.2C rise	1.6C rise	3.0C rise	Specific to Lesser Antilles	Bowden et al. (2020) Cantet et al. (2014)
	East Atlantic	Hotter	Average annual temperature compared to 1971-2000	1.5-2C rise	2.5C rise	NA	NA	Low-confidence, specific to Sao Tome and Principe	Chou et al. (2020)
	Med	Hotter, especially in summer	Average maximum daily temperature during summer compared to 1970-2000	1.6-1.9C rise	2-2.5C rise	NA	NA	Specific to Sicily, Crete and Cyprus	Varotsos et al. (2021)
	Pacific	Hotter	Average temperature compared to 1986-2005	0.5-1.5C rise	1.0-2.0C rise	1.0-2.0C rise	2.0-4.0C rise	Consistent in tropical lattitudes	Lough et al. (2016)
	Global small islands	Hotter	Heat index compared to 1986-2005	1C rise	1.5C rise	1.3C rise	2.8C rise	Equatorial, coastal and continental islands hotter than oceanic	Harter et al. (2015)
ENSO	Pacific	More frequent extreme events	Frequency compared to ~1900-1999	NA	NA	NA	100% more El Ninos, 73-100% more La Ninas	High natural variability limits statistical significance in related patterns	Cai et al., (2014); Cai et al. (2015b)
		Inconclusive change in variability	Amplitude change compared to 1979-2005	0.02C drop	0.01C rise	0.04C drop	0.04C rise	Specific projections are not statistically significant	Cai et al., (2018); Beobide-Arsuaga et al. (2021)
Precipitation	East Caribbean	Slightly wetter, more extreme seasonality	Total rainfall compared to wet/dry season compared to 1971-2001	NA	NA	5% rise/ 10% drop	8% rise/ 15% drop	Significant local variability	Cantet et al. (2014)
	West/ North Caribbean	Drier	Annual rainfall compared to 1986-2005; consecutive dry days compared to 1961-1990	NA	9% less rain	NA	Up to 327% more dry days	Specific to Puerto Rico and US Virgin Islands	Stennett-Brown et al. (2017); Bowden et al. (2020)

	East Atlantic	Inconclusive change	Monthly rainfall compared to 1971-2000	10-25mm rise	10-25mm drop	NA	NA	Low-confidence, specific to Sao Tome and Principe	Chou et al. (2020)
	West Pacific	Wetter, especially after mid-century	Annual average rainfall compared to 1971-2005	2% rise	6% rise	3% rise	8% rise	Low-confidence, specific to Borneo	Sa'adi et al. (2017)
	Central Pacific	Drier, more extreme seasonality	Total rainfall compared to 1975-2005	15% drop	20% drop	17% drop	30% drop	Low-confidence, specific to Hawaii	Timm et al. (2015)
	Southwest Indian Ocean	Drier during the wet season, especially south of 10S	Average change in daily rainfall compared to 1971-2000	NA	NA	NA	0.2 mm per day drop	Low confidence	Lazenby et al. (2018)
	Med	Drier, but highly varied	Annual mean precipitation compared to 1960-1990	70-100 mm drop	60-150 mm drop	NA	NA	Specific to Malta; no significant change in Sicily, Crete and Cyprus	Varotsos et al. (2021)
	Global small islands	Slightly wetter, highly variable	Mean annual precipitation compared to 1986-2005	<1% rise	<1% rise	1.8% rise	3.2% rise	Confidence limited by high standard deviation	Harter et al. (2015)
Tropical Cyclones	North Indian Ocean	More storms in the west, fewer in the east	Frequency compared to 1990-2013	NA	NA	NA	30-60% rise/ 20-40% drop	Specific to Arabian sea/ Bay of Bengal	Bell et al. (2020)
	South Indian Ocean	Fewer storms, fewer strong storms in east	Storm/category 4-5 frequency compared to 1979-2010	NA	NA	NA	20-40% drop/ 0-20% drop		Bell et al. (2019a)
	Northwest Pacific	Slightly more and stronger storms at increasingly high latitudes	Storm density compared to 1970-2000; poleward shift in annual mean of location of maximum intensity compared to 1980-2005	NA	NA	NA	15-40% rise; 0.2°	10-40N, 140-170E	Kossin et al. (2016); Chand et al. (2019)
	Southwest and low-latitude Pacific	Less frequent storms	Storm density compared to 1970-2000	NA	NA	NA	0-20% drop/ 20-30% drop	South/North Pacific up to 20N, 100-140E	Bell et al. (2019a) Chand et al. (2019)
	Northeast Pacific	Less frequent storms	Storm frequency compared to 1970-2016	NA	NA	NA	2-13% drop	No data for Southern Hemisphere	Bell et al. (2019b)
	Central North Pacific	More and stronger storms	Mean annual TC/category 4-5 composition	NA	NA	NA	31%/ 88% rise	Specific to Hawaii	Yoshida et al. (2017)

			compared to 1979-2010						
	Caribbean	Slightly fewer storms	Minor/major cyclones compared to 1984-2013	NA	12% drop/ NC	NA	NA	Specific to lesser Antilles	Cantet et al. (2021)
	East Atlantic	More storms and slightly more frequent intense storms	Storms per decade compared to 1979-2010	NA	NA	NA	0-3 rise	Specific to latitude >15N	Yoshida et al. (2017)
Extratropical cyclone	Med	Decreased frequency but increased intensity	Frequency of storms compared to 1986-2005	NC	NA	12% drop	NA		González-Alemán et al. (2019)

Table 15.3: Percentage of selected islands classified as refugia for biodiversity at increasing levels of warming. While protected land is still ‘protected’ this table demonstrates the difficulty of protecting lands which might be ‘more resilient’ to climate change under increasing levels of warming and current land use practices. Derived from current and future projected distributions of ~130,000 terrestrial fungi, plants, invertebrates and vertebrates (Warren et al., 2018a). Refugia =areas remaining climatically suitable for >75% of the species modelled (Warren et al., 2018b). **Projections:** based on mean impacts from 21 CMIP5 climate model patterns (no dispersal) and elevationally downscaled to 1km under interpolated warming levels derived from RCP 2.6, 4.5, 6.0 and 8.0 (Warren et al., 2018a). First column-set = % island/island chain classified as a refugia based on ***climate alone*** ; second column-set = % natural land projected to be climate refugia — illustrating potential refugia ‘space’ already lost to habitat conversion. **Colour Key**: white > 50%; yellow = 30%-50%; red = 17%-30% and dark red <17% of land classified as refugia.

Island(s)	Climate °C								Climate + Land Use °C							
	0.5	*1*	*1.5*	*2*	*2.5*	*3*	*3.5*	*4*	*0.5*	*1*	*1.5*	*2*	*2.5*	*3*	*3.5*	*4*
Aegean Islands	98	89	85	68	39	19	12	6	66	62	60	50	32	16	11	6
American Samoa	100	100	100	100	83	52	39	25	39	39	39	39	34	24	18	11
Andaman Nicobar	100	95	90	46	7	2	1	0	92	88	84	45	7	2	1	0
Balearic Islands	99	97	95	82	26	6	4	2	29	28	28	25	13	6	3	2
Bangka	100	100	97	3	1	0	0	0	20	20	19	1	0	0	0	0
Barbados	94	67	53	25	5	0	0	0	10	7	6	3	1	0	0	0
Borneo	98	92	89	60	25	14	10	6	67	62	60	43	24	13	10	6
Bougainville	92	81	77	62	39	28	24	19	87	77	74	58	37	27	23	18
British Indian Ocean Territory	100	100	94	0	0	0	0	0	47	47	47	0	0	0	0	0
Corsica	72	61	57	43	29	18	15	10	64	53	50	38	26	16	13	8
Crete	91	83	80	68	52	35	27	20	51	47	46	42	35	26	22	17
Cuba	97	94	92	69	14	4	3	1	48	46	45	36	10	4	3	1
Cyprus	53	51	49	44	32	20	14	8	48	46	44	37	24	14	9	6
Dominica	79	66	63	51	41	28	20	14	79	66	63	51	41	28	20	14
French Polynesia	100	100	100	100	100	81	68	54	38	38	38	38	38	32	28	23
Galapagos	91	82	79	67	50	27	18	13	93	88	86	74	54	33	21	14
Grenada	73	49	43	29	18	10	6	3	71	48	43	29	18	10	6	3
Guadeloupe	91	71	64	27	19	13	9	6	57	46	42	26	19	13	9	6
Guernsey	100	52	41	0	0	0	0	0	13	7	5	0	0	0	0	0
Hispaniola	77	60	54	35	22	15	12	9	55	43	40	28	19	13	11	8
Indonesia	95	87	81	54	28	17	14	11	60	55	51	36	23	15	12	10
Jamaica	77	65	61	47	31	17	10	5	64	54	51	40	27	15	9	4
Java	91	74	65	37	24	17	13	10	27	24	22	18	14	11	9	7
Kiribati	100	55	38	14	0	0	0	0	15	12	12	5	0	0	0	0

Madagascar	98	90	87	70	47	28	22	13	84	77	73	58	37	21	16	10
Maldives	100	38	1	0	0	0	0	0	16	0	0	0	0	0	0	0
Marajo	100	58	33	0	0	0	0	0	91	55	33	0	0	0	0	0
Marshall Islands	100	99	99	55	22	0	0	0	46	46	46	15	10	0	0	0
Mauritius	100	100	100	100	100	100	92	74	27	27	27	27	27	27	25	23
Micronesia	100	100	100	78	59	31	16	6	86	86	86	72	56	29	15	6
Montserrat	61	43	39	27	20	9	9	4	56	38	35	23	17	9	7	4
Nauru	100	100	97	0	0	0	0	0	11	11	11	0	0	0	0	0
New Caledonia	100	100	99	97	89	62	45	31	76	75	75	74	69	53	41	28
New Guinea	95	84	73	47	32	25	22	19	86	76	67	43	30	23	21	18
Northern Mariana Islands	100	100	99	95	58	29	19	11	49	49	49	46	35	22	16	9
Orinoco Delta	100	31	9	0	0	0	0	0	93	29	9	0	0	0	0	0
Palau	100	79	73	21	0	0	0	0	74	59	55	17	0	0	0	0
Palawan	86	70	64	36	21	12	9	6	55	47	44	31	20	12	9	6
Philippines	90	74	66	41	27	16	12	8	34	30	28	21	15	10	8	6
Prince Edward	100	100	100	100	100	97	9	0	35	35	35	35	35	33	2	0
Puerto Rico	84	66	59	41	25	15	11	7	63	52	49	36	24	14	11	7
Saint Lucia	77	50	45	29	14	6	3	1	72	50	45	29	14	6	3	1
Saint Vincent & the Grenadines	73	57	50	37	27	18	13	8	63	50	44	34	23	15	10	5
Samoa	100	100	100	99	89	67	56	46	34	34	34	34	31	24	22	20
Sardinia	95	87	83	65	34	16	10	5	41	38	37	31	22	12	8	4
Seychelles	100	100	98	83	57	25	16	9	25	25	25	22	18	8	6	5
Sicily	93	84	80	60	35	18	11	7	16	15	15	13	10	7	6	4
Singapore	100	100	100	98	9	0	0	0	14	14	14	13	3	0	0	0
Solomon Islands	93	79	74	48	28	15	10	6	92	78	73	48	28	15	10	6
Sri Lanka	98	94	89	64	23	11	7	5	47	46	44	36	16	7	5	4
Sulawesi	86	75	71	58	44	33	28	23	60	54	52	46	38	30	26	21
Sumatra	96	90	87	65	24	16	13	11	40	37	36	30	18	13	11	9
Sumba	98	90	86	70	49	23	11	4	36	33	31	26	18	9	4	2
Timor	92	84	80	66	48	30	22	15	11	10	9	8	7	5	4	3
Trinidad and Tobago	88	24	16	6	3	1	0	0	64	20	14	6	3	1	0	0
Tuvalu	100	100	100	34	0	0	0	0	3	3	3	0	0	0	0	0
Wallis and Futuna	100	100	100	65	32	11	3	0	35	35	35	33	21	7	1	0

Table 15.5: Summary of inter- and intra-regional transboundary risks and impacts on small islands

Transboundary Risks/Issues	**Small Island examples**	**Reference**
Large ocean waves from distant sources	Unusually large deep ocean swells generated from sources in the mid and high latitudes by extratropical cyclones (ETCs) cause considerable damage on the coasts of small islands thousands of kilometres away in the tropics. Impacts include inundation of settlements, infrastructure, and tourism facilities as well as coastal erosion. These waves can propagate to and influence reef islands in equatorial areas not usually exposed to high energy waves.	Hoeke et al. (2013); Smithers and Hoeke (2014); Shope et al. (2016); Canavesio (2019); Wandres et al. (2020) Jury (2018)

	Examples of extratropical swell waves causing flooding and inundation have been reported throughout the Pacific (French Polynesia, Fiji, Micronesia, the Marshall Islands, Kiribati, Papua New Guinea and the Solomon Islands). Modelling of future wave climates has been carried out for 25 tropical Pacific islands, and results suggests that December–February extreme wave heights will decrease for most islands by 2100 under both an RCP4.5 and RCP 8.5 scenario, although the frequency of the large winter wave events may increase around the Hawaiian Islands. In the Caribbean, northerly swells affecting the islands have been recognised as a significant coastal hazard. They cause considerable seasonal damage to beaches, marine ecosystems, and coastal infrastructure throughout the region.	
Transcontinental dust clouds and their impacts	The transport of airborne Saharan dust across the Atlantic into the Caribbean has been intensively studied. In the West African Sahel, where drought has been persistent since the mid-1960s, analysis has shown that there have been remarkable changes in dust emissions since the late 1940s. Variability in Sahel dust emissions may be related not only to droughts, but also to changes in the North Atlantic Oscillation (NAO), North Atlantic sea surface temperatures and the Atlantic Multidecadal Oscillation (AMO). The frequency of dust storms has been on the rise during the last decade. Forecasts suggest that their incidence will increase further. Transboundary movement of Saharan dust into the island regions of the Caribbean and the Mediterranean has been associated with human health problems including asthma cases in the Caribbean, cardiovascular morbidity in Cyprus, and pulmonary disease in the Cape Verde islands.	Prospero and Lamb (2003); Goudie (2014); Schweitzer et al. (2018); Goudie (2020) Middleton et al. (2008); Martins et al. (2009); Akpinar-Elci et al. (2015); Sakhamuri and Cummings (2019)
Influx of Sargassum from distant sources	Since 2011, the Caribbean region has witnessed unprecedented influxes of the pelagic seaweed Sargassum. These extraordinary sargassum 'blooms' have resulted in mass deposition of seaweed on beaches throughout the Lesser Antilles, with damage to coastal habitats, mortality of seagrass beds and associated corals, as well as consequences for fisheries and tourism. This recent phenomenon has been linked to climate change as well as the possible influence of nutrients from Amazon River floods and/or Sahara dust.	van Tussenbroek et al. (2017); Oviatt et al. (2019) Franks et al. (2016); Putman et al. (2018)
Large-scale changes in the distribution of fisheries resources	Ocean warming and other climatic phenomena (e.g., El Niño Southern Oscillation events and Indian Ocean Dipole) have been linked to observed oceanic shifts in tuna distribution with significant impacts on revenue for vulnerable small island states that depend on fisheries licences (e.g., 98% of national income in Tokelau, 66% of national income in Kiribati). The projected eastward redistribution of skipjack and yellowfin tuna due to climate change is expected to reduce the total tuna catch within the combined EEZs of the 10 Pacific Island Countries and territories (PICTs) where most purse-seine activity occurs by approximately 10% by 2050. Projected increases in tuna biomass have been anticipated for Ascension Island and Saint Helena in the South Atlantic.	Bell et al. (2018); SPC (2019); Oremus et al. (2020); Bell et al. (2021); Townhill et al. (2021)

Movement and impact of introduced and invasive species across boundaries	The spread of invasive alien species (IAS) is regarded as a significant transboundary threat to the health of biodiversity and ecosystems worldwide. The extent to which IAS (both animals and plants) successfully establish themselves at new locations in a changing climate will be dependent on many variables, but non-climate factors such as transmission pathways, suitability of the destination, ability to compete and adapt to new environments, and susceptibility to invasion of host ecosystems are deemed to be critical. Modelling studies have been used to project the future 'invisibility' of small island ecosystems subject to climate change and therefore to anticipate marine and terrestrial habitat degradation in the future. Evidence suggests that hurricanes may have hastened the spread of highly invasive Indo-Pacific lionfish (Pterois volitans) throughout the Caribbean in recent years. Two IAS, the Common Green Iguana (*Iguana iguana*) and Cuban Treefrog (*Osteopilus septentrionalis*) were reported in the Caribbean island of Dominica, following the passage of TC Maria in 2017. Observations 7 months after the hurricane, within close proximity to ports, suggest that these animals were stowaways on ships or within relief containers.	Russell et al., 2017) Vorsino et al. (2014); Taylor and Kumar (2016b) Johnston and Purkis (2015); van den Burg et al. (2020)
Spread of pests and pathogens within and between island regions	Increased climate instability has contributed to the emergence and spread of serious diseases carried by mosquitoes such as dengue, chikungunya and zika. The incidence and severity of mosquito-borne diseases have increased significantly in Pacific, Indian Ocean and Caribbean islands during the past 10 years, which calls for a better understanding of how climate change is shaping disease prevalence and transmission. Rising sea temperatures are thought to increase the frequency of disease outbreaks affecting reef-buildings. Of the range of bacterial, fungal and protozoan diseases known to affect stony corals, many have explicit links to temperature. Global projections suggest that disease is as likely to cause coral mortality as bleaching in the coming decades at many localities, with effects occurring earlier at sites in the Caribbean compared to the Pacific and Indian oceans. Model hindcasts suggest that climate-driven changes in sea surface temperature, as well as extreme heatwave events have all played a significant role in the spread of white-band disease throughout the Caribbean. Global food security is threatened by climate-related increases in crop pests and diseases. Black Sigatoka disease of bananas has recently completed its invasion of Latin American and Caribbean banana-growing areas. Infection risk has increased by a median of 44.2% across the Caribbean since the 1960s, due to increasing canopy wetness and improving temperature conditions for the pathogen.	Cao-Lormeau and Musso (2014); Caminade et al. (2017); Pecl et al. (2017); Filho et al. (2019) Maynard et al. (2015); Randall and van Woesik (2015) Bebber (2019)

Human migration and displacement	Currently there is limited empirical evidence that long-term climate change is driving transboundary human migration from islands, however following Hurricane Maria, Puerto Rico witnessed "depopulation" of 14% in only 2 years as a result of emigration to the US mainland.	Campbell (2014a); Melendez and Hinojosa (2017)
Transboundary risks to island food security. COVID-19 caused disruptions to food supply and disaster risk management operations	While SIDS are a diverse group of nations, most share such characteristics as limited land availability, insularity, susceptibility to natural hazards that make them particularly vulnerable to global environmental and economic change processes leading to regional food insecurity. The Pacific Islands Forum Secretariat (PIFS) has established a transboundary Framework for Action on Food Security, that promotes cooperation, investments, research and development, capacity-building, and adaptation to mitigate climate change threats.	Connell (2013) Islam and Kieu (2020); Sheller (2020)

Table 15.6: Adaptation options aimed at reducing Key Risks in small islands.

Key Risks	Risk-oriented adaptation options		Evidence and agreement	Implementation	Key enablers	Reduction of exposure and vulnerability	Co-benefits	Disbenefits
KR1. Loss of marine and coastal biodiversity and ecosystem services	EbA measures (15.4.4)	MPAs; paired terrestrial and MPAs	Medium evidence, low agreement with regard to climate change adaptation and benefits	Widespread across small islands, with climate resilience being a target of some MPAs	Strong governance and sufficient financial resources	Reduces the ecosystem exposure to human disturbances, increasing their resistance and resilience to climate events	For biodiversity, food supply, economics, human health and well-being	
		Active restoration of coastal and marine ecosystems	Limited evidence, low agreement with regard to long-term success	Mostly small-scale: replanting of mangroves, seagrasses and beach vegetation; transplantation of corals; beach nourishment	Funding: adaptation taxes and levies imposed on tourism; blue bonds; public-private partnerships	Reduces the vulnerability of natural ecosystems by increasing their resilience	Improved water quality; reduction in coastal erosion and flood risks; economic benefits	
	Hard protection (15.5.1)	Hard structures designed to enhance marine biodiversity	Medium evidence, medium agreement	Artificial reefs	Funding: adaptation and environmental taxes and levies, with limited evidence of direct reinvestment in conservation and management	Uncertainty on reduction of exposure and vulnerability of marine ecosystems; reduces the exposure of population and infrastructure to coastal risks	For food supply, economies (tourism), human health and well-being	
	Diversifying livelihoods (15.5.6)	Diversifying fisheries livelihoods (e.g. to aquaculture and tourism),	Limited to medium evidence,	Examples in the Caribbean region and in the	Improved governance and cooperation (e.g. through regional	Reduces exposure and vulnerability	Sustainably managed fisheries, improved food and	

		changing fishing grounds and/or target species	medium agreement	Pacific and Indian Oceans	strategies); weather insurance to enhance resilience	of livelihoods through the diversification of income and spreading of risks; targeting less offshore pelagic species reduces exposure of coastal habitats to overfishing	income security, greater economic and social resilience	
	Reef-to-ridge ecosystem management (Figure 15.4)	Improved land use as a driver of marine ecosystem health, including better management of forests, nutrients and waster water upland catchments	Limited evidence, medium agreement	Mostly in the Caribbean region and Pacific	Improved governance	Reduces the exposure of coral reefs to human degradation, increasing their resilience	Improved ecosystem protection services (e.g. against flooding, landslides and mudflows), biodiversity, human health and livelihoods	
KR3. Loss of terrestrial biodiversity and ecosystem services	Decreased deforestation (15.5.4)		Limited to medium evidence, high agreement	Mostly in the Caribbean region and Pacific	NDC, external and long-term funding, engagement of local landowners and resolution of land ownership issues, gender sensitive participation	For example, increase in forest extent, reduction in human exposure to natural disasters (hurricanes, landslides), improvement in vulnerability assessment scores	Increased connectivity between forest fragments, reduced erosion, improved water supply and quality, improved human health and sanitation, improved livelihoods and soil health; decreased poverty; supports global mitigation	

	Increased reforestation (native species) (15.5.4)	Towards habitat connectivity, heterogeneity and diversity	Medium evidence, high agreement	Relatively widespread, with examples in the Caribbean region and Pacific	NDC, funding, technical assistance, supply materials, provision of land, awareness raising, enforcement of policies, sense of shared responsibility, inclusion of Indigenous knowledge and local knowledge, social capital	Generally limited evidence, lack of long-term monitoring	Increased DRR; fewer floods and landslides; reduced erosion; increased human health and well-being; increased quality of ecosystem services; increased adaptive capacity; supports global mitigation	
	EbA (15.5.4)	Agroforestry and other silvicultural/agroecological practices (e.g. climate-smart agriculture)	Medium evidence, high agreement	Widespread in the Caribbean region and Pacific Ocean	NDC, shared access and benefit, local knowledge and training, farmers, private sector for developing technology, financing, data availability; political, institutional and socioeconomic conditions	Limited examples, some increases in adaptive capacity	Improved climate change awareness, increased well-being, improved gender equity, improved productivity and livelihoods	
	Watershed management/conservation (15.5.4)	Reforestation, slope revegetation	Medium evidence, high agreement	Widespread (e.g. in the Caribbean region and Pacific Ocean)	Less socially and politically acceptable than engineering solutions; communication and trust between stakeholders; sustainable financing mechanisms; island remoteness barrier to logistical implementation	Yes, through improved water security, reduced adaptation costs, reduced vulnerability to drought	DRD, improved climate change awareness, increased water security and quality, reduced run-off and sedimentation, increased well-being and financial stability	
	Ridge-to-reef ecosystem management (Figure 15.4)	Improved land use as a driver of terrestrial ecosystem health	Medium evidence, high agreement	See above	See above	Limited but slowly increasing evidence to date		

	Increasing the connectivity of Protected Areas (Pas) across elevation/climatic gradients to facilitate climate-driven redistribution of species (Figure 15.4)	Establishment of new PAs, forested migration corridors across elevation/climatic gradients, improving landscape connectivity by permanent protection of stepping stones	Very limited evidence, high agreement	Low degree of new implementations due to terrain limitations combined with competition from human land use needs; large variation in PA coverage among islands	Conservation of larger areas of forest habitat surrounding PAs, reforestation of degraded areas, increasing and enforcement of forest cover within PAs, policies towards the coordination of conservation actions/partnerships, incorporation of 'Other Effective area-based Conservation Measures' (OECMs)	Yes, especially if landscape connectivity is improved (migration corridors)	Improved water security, improved coastal ecosystem health, greater resiliency and recovery from wildfires, reduced pollution, DRR	May facilitate movement of Invasive Alien Species
	Eradication of Invasive Alien Species (IAS) (15.3.3.3)		Robust evidence, high agreement	Widespread (>700 islands)	Integration of changing climate conditions within ongoing prevention, control and eradication strategies, prevention via ongoing vigilance and biosecurity via quarantine, control and monitoring of incoming cargo and goods into islands	Yes, positive demographic and distributional responses of native species following eradication of IAS	Food security, protection of ecosystem health and services, increased livelihood security	A few native species harmed by eradication process
KR4. Water insecurity	Rainwater harvesting (15.3.4.3)		Robust h evidence, high agreement	Widespread across small islands (e.g. Jamaica, Barbuda, Solomon Islands)	Socio-cultural and financial	Yes	Biodiversity (watershed protection); health; economic (reduced dependence on public supply); food security	Dependent on mode of implementation. Nothing mentioned in the chapter.
	Desalination (15.6.1)		Limited evidence, high agreement	Relatively limited (e.g. Maldives)	Financial	Yes	Health; economic (reduced dependence on public supply)	Energy intensive (carbon footprint)

	Reforestation (15.5.4)		Medium evidence, high agreement	Examples reported in the Caribbean and Pacific (e.g. Fiji, Papua New Guinea)	Governance - whole-of-island approaches foster integrated management practices in small islands	Yes, through supporting wetland-oriented tourism	Economic (agroforestry); biodiversity (watershed restoration); food security; disaster risk reduction	Dependent on mode of implementation. Nothing mentioned in the chapter.
	Protected Area Management (terrestrial) (15.5.4)		Medium evidence, high agreement	Widespread across small islands (e.g. Samoa, Jamaica, Haiti, Grenada)	Financial/governance	Yes, through soil stabilization and sequestration of pollutants	Biodiversity (forest conservation); disaster risk reduction	
KR5. Destruction of settlements and infrastructure	Hard protection (15.5.1)		Medium agreement, limited evidence with regard to climate change adaptation and success	Widespread in both urban and rural areas of the Caribbean, Pacific and Indian Oceans	External funding; socio-cultural (meets the preference of the population); political-institutional (e.g. supported by business-as-usual approach of coastal risks); technical (requires materials and skills)	Reduces exposure in some places but not in others; increases vulnerability	Limited evidence of co-benefits	Beach loss; erosion acceleration; ecosystem degradation through material extraction; increased SLR impacts
	Accommodation (15.5.2)		Limited evidence with regard to climate change adaptation and success	Relatively limited	Technological, financial, institutional, sociocultural	Limited evidence to date	Maintains the functionalities of coastal systems and allows their maintenance through landward migration, under SLR	
	Advance with land raising and/or through the creation of artificial islands (15.5.2)		Limited evidence with regard to climate change adaptation (driven by population	Limited (e.g. Hulhumale', Maldives)	Technological, financial, institutional, sociocultural, high potential in urban (compared to rural) areas	Reduces population exposure where high standard as in Hulhumale', Maldives	Offers new land for economic development, generates revenues through sale or lease of land in urban areas	Widespread ecosystem destruction, increased negative impacts of SLR

			growth in the Maldives)					
	Migration including planned resettlement (15.5.3)		Limited evidence, low agreement with regard to climate change adaptation	Village-scale planned resettlement supported by government policy/legislation in the Pacific	Participatory inclusion of all social groups; financial (for small and remote communities); social-cultural connections; strong governance frameworks; enabling legislation; land availability or ownership; conditions in receiving locations; technical support	Reduced exposure locally; has created new vulnerabilities at some locations by bearing significant economic cost, impacting social capital and reducing access to services	New livelihood opportunities	Loss of cultural heritage, impacts on receiving communities
	EbA measures (15.4.4)		Medium agreement, medium evidence	Increasingly experienced; includes artificial reefs, beach nourishment and vegetation (including mangrove) restoration	Environmental/physical conditions; social acceptability; technical capacities (enhanced by external support); funding; inclusion in national adaptation policies	Limited evidence to date	Biodiversity strengthening; increased food supply; increased human health and well-being	
KR6. Health degradation	Increasing public awareness of health risks associated with climate change; providing training to health sector staff; improving reliability and safety of water storage practices (15.6.2)		Limited evidence	Few examples	Financial and human resources to implement options; early warning and response systems; integrating climate services into health decision-making systems; public uptake and buy in; improving health data collection systems	Primarily reduces vulnerability	Increased water security	

KR7. Economic decline and livelihood failure	Circular migration (15.5.3)		Limited evidence with regard to climate change adaptation (mostly driven by economic or social factors)	Examples in Tuvalu from outer to capital atoll and locations overseas	Labour and education opportunities in Funafuti, Tuvalu, and overseas	Yes on Namumea Atoll, Tuvalu	Job and education for migrants	
	Diversifying livelihoods (15.5.6)		Limited to medium evidence, low agreement	Observed in the Caribbean region and Pacific	Use of ndigenous knowledge and local knowledge and changing fishing areas; investment in technology and education	Yes in documented places (e.g. Antigua, Vanuatu, Madagascar, Dominican Republic)	Reduction of pressure on previous fishing areas	Greater catch putting increasing pressure on fish stock
	Improved technology & equipment/training (15.5.6)		Limited evidence, medium agreement	Examples in the Caribbean region and Pacific	Investments in technologies and education (e.g. irrigation technologies, growing salt-tolerant crops and relocating crop cultivation in Jamaica)	Yes in documented places	New technologies and education strengthening	
	Livestock husbandry (15.5.6)		Limited evidence	Limited (e.g. small-scale livestock husbandry in Jamaica)	Farm inputs and investments in technologies and education	No evidence to date. Limited examples of successful livestock husbandry only in Jamaica	Investments in farm inputs	
	Adaptive finance/education (15.5.6)		Limited evidence, medium agreement	Limited (e.g. in Puerto Rico, women engage in new	Tourism income; investment in education and capacity building;	Yes, reduces risk and avoids negative	Generates opportunities (e.g. for wetland tourism)	

				commercial enterprises that do not rely on traditional coffee supply chains or government assistance)	working with nature and EbA	knock-on effects		
	Product/Market diversification (15.5.6)	Diversity of crops, gardening in different areas, storage and preservation of foodstuffs, engagement of women in new commercial enterprises	Medium evidence, high agreement	Examples in the Caribbean region and Pacific	Availability of crops and land, new markets	Reduces vulnerability to tropical cyclones in Fiji and Vanuatu; new markets in Puerto Rico	Increases food security and improves nutrition; increases income security	
	Adaptation in tourism policies (15.5.6)		Limited evidence, high agreement	Limited (e.g. in the British Virgin Islands, policies like adaptation taxes and levies imposed on tourism can provide funding for adaptation measures)	Tourism regulations and policies that mainstream climate change adaptations; taxes and levies imposed on tourism	Limited evidence in reducing vulnerability		
KR8. Loss of cultural resources and heritage	Integrating Indigenous Knowledge and local knowledge (IKLK) with western science to provide integrated approaches to climate change (15.6.5)		Medium evidence, high agreement	Reported in the Pacific and Caribbean	Use of IKLK for preparing for disasters and understanding environmental change; social networks in sharing information and helping others; ecotheology increasing people's awareness of the environment	Yes, can reduce vulnerability when IK LK supports robust adaptation; No, can increase vulnerability if IKLK no longer provides	Can increase climate change information and its understanding in communities, and increase culturally appropriate climate adaptation	Reports from Vanuatu indicates that IK LK are at times inaccurate (eg seasonal calendars, biophysical weather indicators) due to climate change

						accurate information		
	Hard protection (15.5.5.1)		Medium agreement, limited evidence with regard to climate change adaptation and success	Widespread in protecting cultural sites and villages in both urban and rural areas of the Caribbean, Pacific and Indian Oceans	External funding; socio-cultural (generally meets the preference of the population); political-institutional (e.g. supported by business-as-usual approach of coastal risks); technical (requires materials and skills)	Reduces exposure in some places but not in others; increases vulnerability	Limited evidence of co-benefits	Beach loss; erosion acceleration; ecosystem degradation through material extraction; increased SLR impacts

Table 15.7: Enabling Conditions and Factors for Adaptation in Small Islands

Enabling Conditions and Factors for Adaptation		
Enabler	Example	Reference
Knowledge (Indigenous, Local, External)		
IKLK in developing adaptation strategies (soft protective structures; disaster preparedness)	Using IKLK in identifying Indigenous vegetation (e.g., ecosystem-based adaptation) to reduce erosion (Samoa, Vanuatu)	Crichton and Esteban (2018); Nalau et al. (2018b)
	Pacific storm prediction, disaster preparedness	Chand et al. (2014); Kuruppu and Willie (2015); Granderson (2017)
	Shared resource governance and understanding of linkages between sectors and ecosystems based on IKLK (e.g., Lomanu Gau village initiative (Fiji)	Remling and Veitayaki (2016)
Increased access to climate information	Increased access to climate information increasing individuals will and capacity to support/take adaptive actions (Fiji)	Di Falco and Sharma-Khushal (2019)
	Dissemination of adaptation skills and significance to youth (e.g., Ecocamps in Fiji)	McNaught et al. (2014)
Increased access to climate information (continued)	Pacific women's improved participation in adaptation processes via training, access to information and decision-making	McLeod et al. (2018)
	Improved climate data quality, management and associated observation, modelling and information services	Martin et al. (2015); Hermes et al. (2019)
	Caribbean: Improved climate data quality, management and associated observation, modelling and information services	Trotman et al. (2018)
	Provision of user-tailored products and services through knowledge co-production processes	SPREP (2016a)
Economy and Finance		
Economic diversification and shifting to CRDPs	Tourism system transitions/cooperation from tourism sector	Loehr (2019); Mahadew and Appadoo (2019); Loehr et al. (2020); Sheller (2020)
Finance models for adaptation	Innovative financing models that enable adaptation (e.g., Seychelles)	Rambarran (2018)
	Parametric fisheries insurance products to increase fishery resilience funded by Caribbean Catastrophe Risk Insurance Facility (Grenada and Saint Lucia)	CCRIF (2019)
Transregional trade agreements/associated pressure	Revised socio-political arrangements for better fisheries management (Solomon Islands)	Keen et al. (2018)
Economic viability via revenue from sale of new land	Maldives land raising on Hulhumale	Bisaro et al. (2019)
	"Safe island development programme" after 2004 Indian Ocean Tsunami in the Maldives	Shaig (2008)
Government subsidies	Tuamotu's government subsidy of raised houses	Magnan et al. (2018)
Co-investments and cooperation between agencies (donors, governments)	Tuvalu use of beach nourishment in collaboration with JICA	Onaka et al. (2017)
Diversification of livelihoods as basis for economic activity	Coastal fishers' diversification of livelihoods into the tourism sector (Vanuatu and Madagascar)	Blair and Momtaz (2018)

	Fishermen varying fishing practices and locations depending on environmental conditions (e.g., Dominican Republic)	Karlsson and McLean (2020)
Governance		
Changed governance arrangements resulting in improved coordination	Improved governance arrangements: Cross-sectoral and cross-agency coordination (e. g. Vanuatu)	Webb et al. (2015); Nalau et al. (2016)
Changed governance arrangements resulting in improved coordination (continued)	Agency explicitly tasked with coordinating sectors and services for climate resilience across government (Dominica)	Turner et al. (2020)
	Efficient and coordinated distribution of climate adaptation support across national projects and departments (e.g., Samoa)	McGinn and Solofa (2020)
New strict/explicit building codes	Caribbean infrastructure (esp. housing and hotels) now must be built to withstand strong hurricanes	Mycoo (2018a)
Localising climate adaptation plans, frameworks and policies	Pacific Adaptive Capacity Framework Framework for the Disaster and Climate Resilient Development in the Pacific (FRDP) Island-centric adaptation policy and planning	Warrick et al. (2017) SPC (2016) Schwebel (2017)
Social and cultural		
Social networks and capacity in disaster recovery	Support of social networks in hurricane recovery, access to livelihood opportunities (e.g., Dominica)	Turner et al. (2020)
	Increased Indigenous resilience and adaptive capacity via social networks and capital (e.g., Samoa)	Petzold and Ratter (2015); Parsons et al. (2018)
	Informal credit for fishermen at food stores during and after disasters (e.g., Belize and Dominican Republic)	Karlsson and McLean (2020)
Social networks and traditional familiarity with barter/microfinance	Community-level fundraising (e.g., Samoa, Solomons, Jamaica)	Birk and Rasmussen (2014); Carby (2017); Crichton and Esteban (2018); Parsons et al. (2018); Nunn and Kumar (2019a)
Maintenance of home community	Circular migration between Tuvalu and overseas	Marino and Lazrus (2015)
Empowerment of the migrating individuals	Relocations of villages (Fiji)	Marino and Lazrus 2015)

Table 15.8: Research Gaps in Small Islands

Research Gap	Elaboration
Unavailability of adequately downscaled climate data	There is a lack of oceanographic (e.g. tidal), meteorological, high resolution topographic and bathymetric data, as well as future sea-level and wave climate projections for most islands, which severely constrain modelling studies and therefore improved understanding of future coastal flooding, erosion, and rates of saline intrusion into aquifers (Giardino et al., 2018; Lal and Datta, 2019)
	There is a need for further developing context-specific numerical models, especially through the inclusion of sediment transport, production and delivery (Shope and Storlazzi, 2019), coastal and marine ecosystems' responses (Beetham et al., 2017), and various societal responses (e.g., engineering and ecosystem-based solutions (Giardino et al., 2018)) under different climate change and SLR scenarios.
	The complexity and specificities of small island environments and unavailability of robust baseline data considerably challenge modelling studies in small islands contexts, as reflected by the serious limitations of global modelling impact studies for these (Mentaschi et al., 2018; Vousdoukas et al., 2020).

	Data and model developments are therefore urgently needed to assess the future habitability or exploitability of the islands that are the most critical to small island countries and territories, and to help identify and promote appropriate (especially in technical terms) solutions.
	Adequately downscaled Regional Climate Model (RCM) data (sub-5 km^2) is also required to conduct modelling assessments for small island terrestrial ecosystems. This is particularly needed for islands with complex topography which could be important in providing much-needed climate refugia for the survival of narrow range species such as endemics (Balzan et al., 2018). Such spatial data could be used to maximize the potential of islands to deliver critical ecosystem services (Katovai et al., 2015; Balzan et al., 2018).
	Widely used WorldClim data may not be suitable when applied to the small island context (Box CCP1.1) Without such data, robust ecosystem based adaptation strategies such as climate-smart protected area planning and management under changing climate conditions cannot be developed.
	Thomas and Benjamin (2017) highlighted the lack of data as an area of concern related to assessing loss and damage at 1.5°C. Understanding loss and damage also requires more detail on island-specific losses and damages accruing from anthropogenic climate change impacts. At the moment, such assessments are limited, and most of the small islands have not yet documented these factors in their national adaptation plans or policies (Handmer and Nalau, 2019). There is a need for specific studies also on biophysical variables and species (e.g. impact of temperature rise on mangroves); long term impacts of ocean acidification on species, including relationship to disease outbreaks, and changing breeding grounds of marine species and impacts on fisheries and marine-based livelihoods; incorporating biophysical feedback and interconnectivity of environments into models; and more detailed datasets (e.g. bathymetry, coastal assets) (World Bank, 2016; McField, 2017; Wilson, 2017).
	There is need for new research that investigates the variability of vulnerability within and between islands and states, typologies of best practice (Oculi and Stephenson, 2018), frequency of knowledge sharing among islands and regions (Foley, 2018), identification of regional framework mechanisms, and mapping the complex impact and hazard interactions at a regional scale (Duvat et al., 2017b; Neef et al., 2018; Scandurra et al., 2018; Thiault et al., 2018). Research needs to also examine resilience-building efforts within the four domains of islandness (boundedness, smallness, isolation, and littorality) to effectively capture subjective nuances associated with climate development efforts on islands (Kelman, 2018).
	Research gaps in place-based assessments of social service bundles coupled with policy actions (Balzan et al., 2018) highlight the need for new knowledge to strengthen communication, collaboration and networks between academia, donors, the private sector, community and government (Allahar and Brathwaite, 2016; Schipper et al., 2016) so as to improve understanding of vulnerability and resilience in small islands.
Vulnerability and Resilience	A paucity of research exists currently on the vulnerability of island ecosystem services to climate change (Balzan et al., 2018). While there is rich scientific evidence on the pressures of habitat loss and degradation, impacts of natural hazards and invasive species, far less is known about the interactions of these factors with adaptive capacity and livelihood conditions on islands. In small island contexts, there is a specific need for assessing the effectiveness and cost of ecosystem - and community-based solutions where the latter have been implemented (Filho et al., 2020). The design of generic assessment methods and tools is required to allow for comparative analyses that will, in turn, provide useful guidance for the promotion of context-specific adaptation strategies (Blair and Momtaz, 2018). For many of the small islands, especially SIDS, the economic valuation of marine and coastal ecosystem services – coastal protection, fisheries, tourism - is of great importance, as well as the subsequent losses in these sectors and related livelihoods due to climate change impacts (Waite et al., 2014; Schuhmann and Mahon, 2015; World Bank, 2016; Layne, 2017; Duijndam et al., 2020). There are few integrated modelling studies to inform future habitability of differentiated small island types and how these models can inform decision support processes for ridge to reef stewardship (Povak et al., 2020). Existing studies (Rasmussen et al., 2018) have progressed knowledge since AR5, but island-specific analyses are required to robustly estimate the future ability of land to support life and livelihoods, taking into account multiple climate-drivers, future population exposure, and adaptation responses.
	More research is also needed in understanding how ecosystem benefits are modified under changing climate conditions and how these benefits can be quantified (Doswald et al., 2014). For example, many small islands lack comprehensive (and disaggregated) data related to food security which makes it challenging to attribute climate impacts on local food systems (Taylor et

	al., 2019). Balzan et al. (2018) highlight the importance of quantifying the role of biodiversity in delivering key ecosystem services and demonstrate how such data could provide insights on the interrelatedness of island ecosystems and transboundary service benefits.
Adaptation	In the last decade or so, there has been a significant increase in climate-related financing for small island states. However, monitoring and tracking of funding and metrics to evaluate overall impact are lacking (Boyd et al., 2017; Mallin, 2018). Research into adaptation costs could benefit from the inclusion of indirect effects of climate change such as psychological costs (Vincent and Cull, 2014; Gibson et al., 2019) but to date this research is missing. Greater effort could also be placed on quantifying the relationship between adaptation costs and adverse events (Adelman, 2016). There is also a need for overall land use planning guidelines in small coastal communities, including small islands (Major and Juhola, 2016). The usefulness and utility of insurance mechanisms for building resilience to climate hazards require up to date information on assets at risk (Tietze and van Anrooy, 2018) and further exploration of adaptation measures in small island contexts (Baarsch and Kelman, 2016). Additionally, the differences between theoretical adaptation practices and observed results from actual implementation, along with the integration of IKLK and external knowledge are currently not well understood (Mercer et al., 2014b; Kelman, 2015b; Saint Ville et al., 2015; Robinson and Gilfillan, 2016; Robinson, 2017b). Documenting experience-based knowledge of adaptation projects and programme implementation could fill important data gaps. At the project design stage, paucity of climate finance data is a barrier to accessing climate finance (Bhandary et al., 2021).
	Although studies examining the association between climate and weather extremes, events and conditions and mobility in small islands have increased since AR5 (Birk and Rasmussen, 2014; Kelman, 2015a; Connell, 2016; Stojanov et al., 2017; Barnett and McMichael, 2018), few studies robustly examine attribution of migration of small island populations, communities and individuals to anthropogenic climate change and other non-climate migration drivers. Biophysical, socio-economic and in-situ adaptation threshold that force small island populations to migrate remains under-explored (Barnett, 2017; Handmer and Nalau, 2019). The implications of forced and voluntary immobility (Allgood and McNamara, 2017; Farbotko, 2018; Suliman et al., 2019), the socio-economic, health, psychological and cultural outcomes of climate migrants, and gender dimensions of climate migration all remain under-researched.
	Limits to adaptation is still a largely under-researched topic globally (Nalau and Filho, 2018) and specifically in small island contexts, as are the linkages between adaptation limits, loss and damage and transformative adaptation (Thomas et al., 2020). In terms of projected risks and adaptation responses, further work is needed to improve knowledge of commonalities, differences, successes, and failures of natural and human adaptation responses (Kuruppu and Willie, 2015). One of the failings of current literature on limits to adaptation revolves largely on the use of barriers for sector-specific or small-scale scenarios, that provide an understanding only for that particular scenario and does not identify common constraints (Kuruppu and Willie, 2015). Research gaps on loss and damage include: how to assess the economic costs of loss and damage; mechanisms to develop robust policies in small island contexts; specific data on experienced loss and damage across socio-economic groups and demographics; monitoring and tracking of slow onset events (Thomas and Benjamin, 2017; Thomas et al., 2020) and the non-economic aspects including sense of place, health and community cohesion (Thomas and Benjamin, 2019).
	More studies are needed on the role that organisations (international, national and regional) play in adaptation efforts – their effectiveness at achieving desired outcomes, roles and accountability (Robinson and Gilfillan, 2016; Scobie, 2016; Mallin, 2018). It is also important that the impacts of socio-political relations inter-state are researched (Belmar et al., 2015) and more focus on climate justice (Baptiste and Devonish, 2019; Moulton and Machado, 2019; Gahman and Thongs, 2020) and gender are similarly needed (Mcleod et al., 2018). Given the high number of place-specific case studies in adaptation literature, more reviews are needed that synthesise key lessons and principles of adaptations in small island contexts from this knowledge. Further research is also needed to capture the lessons from COVID-19 response in small islands and how these could enable more robust adaptation and climate resilient development transitions as has been suggested at a broader scale by Schipper et al. (2020). There is also little to no information on impacts upon terrestrial and freshwater biodiversity from the relocation of coastal human populations inland due to SLR.

References

Abella Perez, E., A. Marco, S. Martins and L. A. Hawkes, 2016: Is this what a climate change-resilient population of marine turtles looks like? *Biological Conservation*, 193, 124-132, doi:10.1016/j.biocon.2015.11.023.

Abram, N. et al., 2019: Chapter 1: Framing and Context of the Report. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H. O., D. Roberts, V. Masson-Delmotte, P. Zhai, Y. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)].

Adelman, S., 2016: Climate justice, loss and damage and compensation for small island developing states. *Journal of Human Rights and the Environment*, 7(1), 32-53, doi:10.4337/jhre.2016.01.02.

Adger, W. et al., 2014: Human security. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change* [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 755-791.

Ainsworth, T. et al., 2016: Climate change disables coral bleaching protection on the Great Barrier Reef. *Science*, 352(6283), 338-342, doi:10.1126/science.aac7125.

Aipira, C., A. Kidd and K. Morioka, 2017: Climate Change Adaptation in Pacific Countries: Fostering Resilience through Gender Equality. In: *Climate Change Adaptation in Pacific Countries: Fostering Resilience and Improving the Quality of Life* [Filho, W. L. (ed.)]. Springer, Germany.

Akpinar-Elci, M., F. Martin, J. Behr and R. Diaz, 2015: Saharan dust, climate variability, and asthma in Grenada, the Caribbean. *International Journal of Biometeorology*, 59(11), 1667-1671, doi:10.1007/s00484-015-0973-2.

Aladenola, O., A. Cashman and D. Brown, 2016: Impact of El Niño and Climate Change on Rainwater Harvesting in a Caribbean State. *Water Resources Management*, 30(10), 3459-3473, doi:10.1007/s11269-016-1362-2.

Albert, S. et al., 2016: Interactions between sea-level rise and wave exposure on reef island dynamics in the Solomon Islands. *Environmental Research Letters*, 11(5), doi:10.1088/1748-9326/11/5/054011.

Alcover, J., A. Sans and M. Palmer, 1998: The extent of extinctions of mammals on islands. *Journal of Biogeography*, 25, 913-918, doi:10.1046/J.1365-2699.1998.00246.X.

Allahar, H. and C. Brathwaite, 2016: Business incubation as an instrument of innovation: the experience of South American and the Caribbean. *International Journal of Innovation*, 4(2), 71-85, doi:10.5585.iji.v4i2.107.

Allgood, L. and K. McNamara, 2017: Climate-induced migration: Exploring local perspectives in Kiribati. *Singapore Journal of Tropical Geography*, 38(3), 370-385, doi:10.1111/sjtg.12202.

Alongi, D. M., 2008: Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science*, 76(1), 1-13, doi:10.1016/j.ecss.2007.08.024.

Alsumaiei, A. and R. Bailey, 2018: Quantifying threats to groundwater resources in the Republic of Maldives Part I: Future rainfall patterns and sea-level rise. *Hydrological Processes*, 32(9), 1137-1153, doi:10.1002/hyp.11480.

Andrew, N. L. et al., 2019: Coastal proximity of populations in 22 Pacific Island Countries and Territories. *PLoS One*, 14(9), e0223249, doi:10.1371/journal.pone.0223249.

Anfuso, G., J. Martinez-del-Pozo and N. Rangel-Buitrago, 2012: Bad practice in erosion management: the Southern Sicily case study. In: *Pitfalls of shoreline destabilization: selected case studies* [Cooper, J. A. G. and O. H. Pilkey (eds.)]. Springer Science Business Media Netherlands.

Anshuka, A., F. Ogtrop and W. Vervoort, 2018: Drought Modelling in Small Island Developing States: A Case Study in Fiji. *Geophysical Research Abstracts*, 20.

Arias-Ortiz, A. et al., 2018: A marine heatwave drives massive losses from the world's largest seagrass carbon stocks. *Nature Climate Change*, 8(4), 338-344, doi:10.1038/s41558-018-0096-y.

Arnold, S. et al., 2018: The significance of climate in the pollinator dynamics of a tropical agroforestry system. *Agriculture, Ecosystems & Environment*, 254, 1-9, doi:10.1016/j.agee.2017.11.013.

Asch, R. G., B. Erisman and E. Treml, 2018: Spawning aggregations act as a bottleneck influencing climate change impacts on a critically endangered reef fish. *Diversity and Distributions*, 24(12), 1712-1728, doi:10.1111/ddi.12809.

Ateweberhan, M. et al., 2013: Climate change impacts on coral reefs: synergies with local effects, possibilities for acclimation, and management implications. *Marine Pollution Bulletin*, 74(2), 526-539, doi:10.1016/j.marpolbul.2013.06.011.

Atteridge, A. and N. Canales, 2017: *Climate finance in the Pacific: an overview of flows to the region's Small Island Developing States. Working Paper No. 2017-04*. Stockholm Environmental Institute, Stockholm, Sweden.

Atteridge, A., N. Canales and G. Savvidou, 2017: *Climate finance in the Caribbean region's Small Island Developing States: Working paper No. 2017-08*. Stockholm Environment Institute.

Baarsch, F. and I. Kelman, 2016: Insurance Mechanisms for tropical cyclones and droughts in Pacific Small Island Developing States. *Jamba: Journal of Disaster Risk Studies*, 8(1), doi:10.4102/jamba.v8i1.288.

Bailey, R. et al., 2016: Assessing regional-scale spatio-temporal patterns of groundwater-surface water interactions using a coupled SWAT-MODFLOW model. *Hydrological Processes*, 30(23), doi:10.1002/hyp.10933.

Baldacchino, G., 2018: Seizing history: development and non-climate change in Small Island Developing States. *International Journal of Climate Change Strategies and Management*, 10(2), 217-228, doi:10.1108/ijccsm-02-2017-0037.
Baldock, T. et al., 2015: Impact of sea-level rise on cross-shore sediment transport on fetch-limited barrier reef island beaches under modal and cyclonic conditions. *Marine Pollution Bulletin*, 97(1-2), 188-198, doi:10.1016/j.marpolbul.2015.06.017.
Balzan, M., M. Potschin-Young and R. Haines-Young, 2018: Island ecosystem services: insights from a literature review on case-study island ecosystem services and future prospects. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 14(1), 71-90, doi:10.1080/21513732.2018.1439103.
Baptiste, A. and H. Devonish, 2019: The Manifestation of Climate Injustices: The Post-Hurricane Irma Conflicts Surrounding Barbuda's Communal Land Tenure. *Journal of Extreme Events*, 06(01), doi:10.1142/s2345737619400025.
Baptiste, A. and R. Kinlocke, 2016: We are not all the same!: Comparative climate change vulnerabilities among fishers in Old Harbour Bay, Jamaica. *Geoforum*, 73, 47-59, doi:10.1016/j.geoforum.2015.05.006.
Barclay, J. et al., 2019: Historical Trajectories of Disaster Risk in Dominica. *International Journal of Disaster Risk Science*, 10(2), 149-165, doi:10.1007/s13753-019-0215-z.
Barkdull, J. and P. G. Harris, 2018: Emerging responses to global climate change: ecosystem-based adaptation. *Global Change, Peace & Security*, 31(1), 19-37, doi:10.1080/14781158.2018.1475349.
Barkey, B. and R. Bailey, 2017: Estimating the Impact of Drought on Groundwater Resources of the Marshall Islands. *Water*, 9(1), doi:10.3390/w9010041.
Barnard, P. et al., 2015: Coastal vulnerability across the Pacific dominated by El Niño/Southern Oscillation. *Nature Geoscience*, 8(10), 801-807, doi:10.1038/ngeo2539.
Barnett, J., 2017: The dilemmas of normalising losses from climate change: Towards hope for Pacific atoll countries. *Asia Pacific Viewpoint*, 58(1), 3-13, doi:10.1111/apv.12153.
Barnett, J. and J. Campbell, 2010: *Climate Change and Small Island States: Power, Knowledge and the South Pacific*. Earthscan, London. ISBN 978-1-84407-494-5.
Barnett, J. and C. McMichael, 2018: The effects of climate change on the geography and timing of human mobility. *Population and Environment*, 39(4), 339-356, doi:10.1007/s11111-018-0295-5.
Barriot, J., J. Serafini, K. Maamaatuaiahutapu and L. Sichoix, 2016: The Island of Tubuai (French Polynesia) Landfall of Cyclone Oli on the 5th of February 2010. *Open Access Library Journal*, 3(e2615), doi:10.4236/oalib.1102615.
Bebber, D. P., 2019: Climate change effects on Black Sigatoka disease of banana. *Philosophical Transactions of the Royal Society B*, 374(1775), doi:10.1098/rstb.2018.0269.
Beca-Carretero, P. et al., 2020: Projected Rapid Habitat Expansion of Tropical Seagrass Species in the Mediterranean Sea as Climate Change Progresses. *Frontiers in Plant Science*, 11, 555376, doi:10.3389/fpls.2020.555376.
Beck, M. W. et al., 2018: The global flood protection savings provided by coral reefs. *Nature Communications*, 9(1), 2186, doi:10.1038/s41467-018-04568-z.
Becken, S., 2019: Decarbonising tourism: mission impossible? *Tourism Recreation Research*, 1-15, doi:10.1080/02508281.2019.1598042.
Becken, S., E. Whittlesea, J. Loehr and D. Scott, 2020: Tourism and climate change: evaluating the extent of policy integration. *Journal of Sustainable Tourism*, 28(10), 1603-1624, doi:10.1080/09669582.2020.1745217.
Becker, M., M. Karpytchev and F. Papa, 2019: Hotspots of Relative Sea Level Rise in the Tropics. In: *Tropical Extremes: Natural Variability and Trends* [Venugopal, V., J. Sukhatme, R. Murtugudde and R. Roca (eds.)]. Elsevier, pp. 203-262. ISBN 9780128092484.
Beckford, C., 2018: Climate change resiliency in Caribbean SIDS: building greater synergies between science and local and traditional knowledge. *Journal of Environmental Studies and Sciences*, 8(1), 42-50, doi:10.1007/s13412-017-0440-y.
Beetham, E., P. Kench and S. Popinet, 2017: Future Reef Growth Can Mitigate Physical Impacts of Sea-Level Rise on Atoll Islands. *Earth's Future*, 5(10), 1002-1014, doi:10.1002/2017ef000589.
Bell, J. et al., 2018: Adaptations to maintain the contributions of small-scale fisheries to food security in the Pacific Islands. *Marine Policy*, 88, 303-314, doi:10.1016/j.marpol.2017.05.019.
Bell, J. et al., 2013: Mixed responses of tropical Pacific fisheries and aquaculture to climate change. *Nature Climate Change*, 3(6), 591-599, doi:10.1038/nclimate1838.
Bell, J. and M. Taylor, 2015: *Building climate-resilient food systems for Pacific Islands*. WorldFish. Program Report: 2015-15, Penang, Malaysia.
Bell, J., M. Taylor, M. Amos and N. Andrew, 2016: *Climate change and Pacific Island food systems: the future of food, farming and fishing in the Pacific Islands under a changing climate*. Available at: https://cgspace.cgiar.org/rest/bitstreams/79049/retrieve.
Bell, J. D. et al., 2015: Diversifying the use of tuna to improve food security and public health in Pacific Island countries and territories. *Marine Policy*, 51, 584-591, doi:10.1016/j.marpol.2014.10.005.
Bell, J. D. et al., 2009: Planning the use of fish for food security in the Pacific. *Marine Policy*, 33(1), 64-76, doi:10.1016/j.marpol.2008.04.002.
Bell, J. D. et al., 2021: Pathways to sustaining tuna-dependent Pacific Island economies during climate change. *Nature Sustainability*, doi:10.1038/s41893-021-00745-z.

Bell, S. et al., 2019a: Projections of Southern Hemisphere Tropical Cyclone Track Density using CMIP5 models. *Climate Dynamics*, 52(9-10), 6065-6079, doi:10.1007/s00382-018-4497-4.
Bell, S. S. et al., 2019b: Eastern North Pacific tropical cyclone activity in historical and future CMIP5 experiments: assessment with a model-independent tracking scheme. *Climate Dynamics*, 53(7-8), 4841-4855, doi:10.1007/s00382-019-04830-0.
Bell, S. S. et al., 2020: North Indian Ocean tropical cyclone activity in CMIP5 experiments: Future projections using a model-independent detection and tracking scheme. *International Journal of Climatology*, 40(15), 6492-6505, doi:10.1002/joc.6594.
Bellard, C., C. Leclerc and F. Courchamp, 2013a: Impact of sea level rise on the 10 insular biodiversity hotspots. *Global Ecology and Biogeography*, 23(2), 203-212, doi:10.1111/geb.12093.
Bellard, C., C. Leclerc and F. Courchamp, 2013b: Potential impact of sea level rise on French islands worldwide. *Nature Conservation*, 5, 75-86, doi:10.3897/natureconservation.5.5533.
Bellard, C. et al., 2014: Vulnerability of biodiversity hotspots to global change. *Global Ecology and Biogeography*, 23(12), 1376-1386, doi:10.1111/geb.12228.
Bellard, C., C. P and T. Blackburn, 2016: Alien species as a driver of recent extinctions. *Biology Letters*, 12(20150623), doi:10.1098/rsbl.2015.0623.
Belmar, Y., K. McNamara and T. Morrison, 2015: Water security in small island developing states: the limited utility of evolving governance paradigms. *Wiley Interdisciplinary Reviews: Water*, 3(2), 181-193, doi:10.1002/wat2.1129.
Benjamin, L., A. Thomas and R. Haynes, 2018: An 'Islands' COP'? Loss and damage at COP23. *Review of European, Comparative & International Environmental Law*, 27(3), 332-340, doi:10.1111/reel.12255.
Beobide-Arsuaga, G., T. Bayr, A. Reintges and M. Latif, 2021: Uncertainty of ENSO-amplitude projections in CMIP5 and CMIP6 models. *Climate Dynamics*, 56(11-12), 3875-3888, doi:10.1007/s00382-021-05673-4.
Bertana, A., 2020: The role of power in community participation: Relocation as climate change adaptation in Fiji. *Environment and Planning C: Politics and Space*, 38(5), 902-919, doi:10.1177/2399654420909394.
Betzold, C., 2015: Adapting to climate change in small island developing states. *Climatic Change*, 133(3), 481-489, doi:10.1007/s10584-015-1408-0.
Betzold, C. and I. Mohamed, 2017: Seawalls as a response to coastal erosion and flooding: a case study from Grande Comore, Comoros (West Indian Ocean). *Regional Environmental Change*, 17(4), 1077-1087, doi:10.1007/s10113-016-1044-x.
Bhandary, R. R., K. S. Gallagher and F. Zhang, 2021: Climate finance policy in practice: a review of the evidence. *Climate Policy*, 21(4), 529-545, doi:10.1080/14693062.2020.1871313.
Bhatia, K. T. et al., 2019: Recent increases in tropical cyclone intensification rates. *Nature Communications*, 10(1), 635, doi:10.1038/s41467-019-08471-z.
Bheeroo, R., N. Chandrasekar, S. Kaliraj and N. Magesh, 2016: Shoreline change rate and erosion risk assessment along the Trou Aux Biches–Mont Choisy beach on the northwest coast of Mauritius using GIS-DSAS technique. *Environmental Earth Sciences*, 75(5), doi:10.1007/s12665-016-5311-4.
Bianchi, C. et al., 2003: Monitoring coral bleaching in the Maldives: lessons to be learned and a new hypotheses. *Oceanis*, 29(3-4), 325-354.
Bindoff, N. et al., 2019: Chapter 5: Changing Ocean, Marine Ecosystems, and Dependent Communities. In: *IPCC Special Report on Ocean and Cryosphere in a Changing Climate* [Portner, H. O., D. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegria, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)].
Biribo, N. and C. Woodroffe, 2013: Historical area and shoreline change of reef islands around Tarawa Atoll, Kiribati. *Sustainability Science*, 8(3), 345-362, doi:10.1007/s11625-013-0210-z.
Birk, T. and K. Rasmussen, 2014: Migration from atolls as climate change adaptation: Current practices, barriers and options in Solomon Islands. *Natural Resources Forum*, 38(1), 1-13, doi:10.1111/1477-8947.12038.
Bisaro, A. et al., 2019: Leveraging public adaptation finance through urban land reclamation: cases from Germany, the Netherlands and the Maldives. *Climatic Change*, 160(4), 671-689, doi:10.1007/s10584-019-02507-5.
Blackburn, S., 2014: The politics of scale and disaster risk governance: Barriers to decentralisation in Portland, Jamaica. *Geoforum*, 52, 101-112, doi:10.1016/j.geoforum.2013.12.013.
Blair, A. and S. Momtaz, 2018: Climate change perception and response: Case studies of Fishers from Antigua and Efate. *Ocean & Coastal Management*, 157, 86-94, doi:10.1016/j.ocecoaman.2018.02.015.
Boger, R., S. Perdikaris and I. Rivera-Collazo, 2019: Cultural heritage and local ecological knowledge under threat: Two Caribbean examples from Barbuda and Puerto Rico. *Journal of Anthropology and Archaeology*, 7(2), 1-14, doi:10.15640/jaa.v7n2a1.
Bordner, A. S., C. E. Ferguson and L. Ortolano, 2020: Colonial dynamics limit climate adaptation in Oceania: Perspectives from the Marshall Islands. *Global Environmental Change*, 61, doi:10.1016/j.gloenvcha.2020.102054.
Borges-Méndez, R. and C. Caron, 2019: Decolonizing Resilience: The Case of Reconstructing the Coffee Region of Puerto Rico After Hurricanes Irma and Maria. *Journal of Extreme Events*, 06(01), doi:10.1142/s2345737619400013.
Bowden, J. H. et al., 2020: High-resolution dynamically downscaled rainfall and temperature projections for ecological life zones within Puerto Rico and for the US Virgin Islands. *Int J Climatol*, 41(2), 1305-1327, doi:10.1002/joc.6810.

Boyd, E. et al., 2017: A typology of loss and damage perspectives. *Nature Climate Change*, 7(10), 723-729, doi:10.1038/NCLIMATE3389.
Bramante, J. F. et al., 2020: Sea Level Rise Will Drive Divergent Sediment Transport Patterns on Fore Reefs and Reef Flats, Potentially Causing Erosion on Atoll Islands. *Journal of Geophysical Research: Earth Surface*, 125(10), doi:10.1029/2019jf005446.
Branoff, B., 2018: Changes in mangrove tree mortality, forest canopy, and aboveground biomass accumulation rates following the 2017 hurricane season in Puerto Rico and the role of urbanization. *bioRxiv*, doi:10.1101/425140.
Briones, F., R. Vachon and M. Glantz, 2019: Local responses to disasters: recent lessons from zero-order responders. *Disaster Prevention and Management: An International Journal*, 28(1), 119-125, doi:10.1108/dpm-05-2018-0151.
Brodie, G. et al., 2020: Seagrass habitat in Tarawa Lagoon, Kiribati: Service benefits and links to national priority issues. *Marine Pollution Bulletin*, 155, doi:10.1016/j.marpolbul.2020.111099.
Brown, C. J. et al., 2017: Tracing the influence of land-use change on water quality and coral reefs using a Bayesian model. *Scientific Reports*, 7(1), 4740, doi:10.1038/s41598-017-05031-7.
Brown, S. et al., 2018: Quantifying Land and People Exposed to Sea-Level Rise with No Mitigation and 1.5C and 2.0C Rise in Global Temperatures to Year 2300. *Earth's Future*, 6, 583-600, doi:10.1002/2017EF000738.
Brown, S. et al., 2020: Land raising as a solution to sea-level rise: An analysis of coastal flooding on an artificial island in the Maldives. *Journal of Flood Risk Management*, 13(S1), doi:10.1111/jfr3.12567.
Bryant-Tokalau, J., 2018a: Handling Weather Disasters: The Resilience and Adaptive Capacity of Pacific Island Communities. In: *Indigenous Pacific Approaches to Climate Change: Pacific Island Countries* [Stewart, P. and A. Strathern (eds.)]. Palgrave Macmillan.
Bryant-Tokalau, J., 2018b: *Indigenous Pacific Approaches to Climate Change: Pacific Island Countries*. Palgrave Studies in Disaster Anthropology, Palgrave Macmillan.
Buggy, L. and K. McNamara, 2016: The need to reinterpret "community" for climate change adaptation: a case study of Pele Island, Vanuatu. *Climate and Development*, 8(3), 270-280, doi:10.1080/17565529.2015.1041445.
Buhr, B. et al., 2018: *Climate Change and the Cost of Capital in Developing Countries: Assessing the impact of climate risks on sovereign borrowing costs*. Imperial College Business School, SOAS University of London.
Butchart, S. et al., 2019: Chapter 3: Assessing progress towards meeting major international objectives related to nature and nature's contributions to people. In: *Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* [Brondizio, E., J. Settele, S. Diaz and H. Ngo (eds.)].
Butcher-Gollach, C., 2015: Planning, the urban poor and climate change in Small Island Developing States (SIDS): unmitigated disaster or inclusive adaptation? *International Development Planning Review*, 37(2), 225-248, doi:10.3828/idpr.2015.17.
Cai, W. et al., 2014: Increasing frequency of extreme El Nino events due to greenhouse warming. *Nature Climate Change*, 4(2), 111-116, doi:10.1038/NCLIMATE2100.
Cai, W. et al., 2015a: ENSO and greenhouse warming. *Nature Climate Change*, 5(9), 849-859, doi:10.1038/nclimate2743.
Cai, W. et al., 2018: Increased variability of eastern Pacific El Nino under greenhouse warming. *Nature*, 564(7735), 201-206, doi:10.1038/s41586-018-0776-9.
Cai, W. et al., 2015b: Increased frequency of extreme La Niña events under greenhouse warming. *Nature Climate Change*, 5(2), 132-137, doi:10.1038/nclimate2492.
Cambers, G., 2009: Caribbean beach changes and climate change adaptation. *Aquatic Ecosystem Health & Management*, 12(2), 168-176, doi:10.1080/14634980902907987.
Caminade, C. et al., 2017: Global risk model for vector-borne transmission of Zika virus reveals the role of El Nino 2015. *PNAS*, 114(1), 119-125, doi:10.1073/pnas.1700746114.
Campbell, D., 2021: Environmental change and the livelihood resilience of coffee farmers in Jamaica: A case study of the Cedar Valley farming region. *Journal of Rural Studies*, 81, 220-234, doi:10.1016/j.jrurstud.2020.10.027.
Campbell, D. et al., 2021: Wild Food Harvest, Food Security, and Biodiversity Conservation in Jamaica: A Case Study of the Millbank Farming Region. *Frontiers in Sustainable Food Systems*, 5, doi:10.3389/fsufs.2021.663863.
Campbell, J., 2014a: Climate change migration in the Pacific. *Contemporary Pacific*, 26(1), 1-29, doi:10.1353/cp.2014.0023.
Campbell, J., 2014b: Development, global change and traditional food security in Pacific Island countries. *Regional Environmental Change*, 15(7), 1313-1324, doi:10.1007/s10113-014-0697-6.
Campbell, J. and O. Warrick, 2014: *Climate Change and Migration Issues in the Pacific*. United Nations Economic and Social Commission for Asia and the Pacific, Fiji.
Canales, N., A. Atteridge and A. Sturesson, 2017: *Climate finance for the Indian Ocean and African Small Island Developing States: Working paper no. 2017-11*. Stockholm Environment Institute.
CANARI, 2020: Rising to the climate challenge: Coastal and marine resilience in the Caribbean, Barataria, Trinidad and Tobago. Available at: https://canari.org/wp-content/uploads/2020/08/CANARI-Coastal-Marine-Resilience-Issue-Paper.pdf.
Canavesio, R., 2019: Distant swells and their impacts on atolls and tropical coastlines. The example of submersions produced by lagoon water filling and flushing currents in French Polynesia during 1996 and 2011 mega swells. *Global and Planetary Change*, 177, 116-126, doi:10.1016/j.gloplacha.2019.03.018.

Cannonier, C. and M. Burke, 2018: The economic growth impact of tourism in Small Island Developing States—evidence from the Caribbean. *Tourism Economics*, 25(1), 85-108, doi:10.1177/1354816618792792.
Cantet, P., A. Belmadani, F. Chauvin and P. Palany, 2021: Projections of tropical cyclone rainfall over land with an Eulerian approach: case study of three islands in the West Indies. *International Journal of Climatology*, 41(51), E1164-1179, doi:10.1002/joc.6760.
Cantet, P., M. Déqué, P. Palany and J. Maridet, 2014: The importance of using a high-resolution model to study the climate change on small islands: the Lesser Antilles case. *Tellus A: Dynamic Meteorology and Oceanography*, 66(1), doi:10.3402/tellusa.v66.24065.
Cantrell, S. et al., 2014: Effects of a simulated hurricane disturbance on forest floor microbial communities. *Forest Ecology and Management*, 332, 22-31, doi:10.1016/j.foreco.2014.07.010.
Cao-Lormeau, V.-M. and D. Musso, 2014: Emerging arboviruses in the Pacific. *The Lancet*, 384(9954), 1571-1572, doi:10.1016/s0140-6736(14)61977-2.
Carby, B., 2015: Beyond the community: integrating local and scientific knowledge in the formal development approval process in Jamaica. *Environmental Hazards*, 14(3), 252-269, doi:10.1080/17477891.2015.1058740.
Carby, B., 2017: Integrating disaster risk reduction in national development planning: experience and challenges of Jamaica. *Environmental Hazards*, 17(3), 219-233, doi:10.1080/17477891.2017.1415864.
Carlson, R. R., S. A. Foo and G. P. Asner, 2019: Land Use Impacts on Coral Reef Health: A Ridge-to-Reef Perspective. *Frontiers in Marine Science*, 6, doi:10.3389/fmars.2019.00562.
Cashman, A., 2014: Water Security and Services in the Caribbean. *Water*, 6(5), 1187-1203, doi:10.3390/w6051187.
Cashman, A. and M. Nagdee, 2017: Impacts of Climate Change on Settlements and Infrastructure in the Coastal and Marine Environments of Caribbean Small Island Developing States (SIDS). *Caribbean Marine Climate Change Report Card: Science Review 2017.*, 155-173.
Cashman, A. and D. Yawson, 2019: Water, Livelihoods, and Migration in SIDS: Climate Change and Future Prospects for Carriacou, West Indies. *Resources*, 8(4), doi:10.3390/resources8040174.
Cauchi, J. P., I. Correa-Velez and H. Bambrick, 2019: Climate change, food security and health in Kiribati: a narrative review of the literature. *Global Health Action*, 12(1), 1603683, doi:10.1080/16549716.2019.1603683.
Cauchi, J. P., S. Moncada, H. Bambrick and I. Correa-Velez, 2021: Coping with environmental hazards and shocks in Kiribati: Experiences of climate change by atoll communities in the Equatorial Pacific. *Environmental Development*, 37, doi:10.1016/j.envdev.2020.100549.
CCCCC, 2012: *Delivering Transformational Change: The Implementation Plan for the CARICOM 'Regional Framework for Achieving Development Resilient to Climate Change' (2011-2021)*. Available at: https://www.caribbeanclimate.bz/2009-2021-regional-planning-for-climate-compatible-development-in-the-region/.
CCRIF, 2019: Caribbean Countries to Benefit from Access to Insurance for the Fisheries Sector.
CDEMA, 2014: *Regional Comprehensive Disaster Management (CDM) Strategy and Results Framework 2014-2024.* . Barbados. Available at: www.cdema.org.
Chacowry, A., L. McEwen and K. Lynch, 2018: Recovery and resilience of communities in flood risk zones in a small island developing state: A case study from a suburban settlement of Port Louis, Mauritius. *International Journal of Disaster Risk Reduction*, 28, 826-838, doi:10.1016/j.ijdrr.2018.03.019.
Chakrabarti, P. et al., 2017: Alternate livelihood development for 'Aila' affected tribal people through aquaculture in Bali Island of the Sunderban, West Bengal, India. *Indian Journal of Fisheries*, 64, doi:10.21077/ijf.2017.64.special-issue.76186-03.
Chambers, L. et al., 2019: Traditional or contemporary weather and climate forecasts: reaching Pacific communities. *Regional Environmental Change*, doi:10.1007/s10113-019-01487-7.
Chambers, L. et al., 2017: A database for traditional knowledge of weather and climate in the Pacific. *Meteorological Applications*, 24(3), 491-502, doi:10.1002/met.1648.
Chand, S. et al., 2014: Indigenous Knowledge for Environmental Prediction in the Pacific Island Countries. *Weather, Climate, and Society*, 6(4), 445-450, doi:10.1175/wcas-d-13-00053.1.
Chand, S. S. et al., 2019: Western North Pacific Tropical Cyclone Tracks in CMIP5 Models: Statistical Assessment Using a Model-Independent Detection and Tracking Scheme. *Journal of Climate*, 32(21), 7191-7208, doi:10.1175/jcli-d-18-0785.1.
Chandra, A. and P. Gaganis, 2016: Deconstructing vulnerability and adaptation in a coastal river basin ecosystem: a participatory analysis of flood risk in Nadi, Fiji Islands. *Climate and Development*, 8(3), 256-269, doi:10.1080/17565529.2015.1016884.
Charan, D., M. Kaur and P. Singh, 2017: Customary Land and Climate Change Induced Relocation—A Case Study of Vunidogoloa Village, Vanua Levu, Fiji. In: *Climate Change Adaptation in Pacific Countries* [Filho, W. L. (ed.)]. Springer, Cham, Switzerland, pp. 19-33. ISBN 978-3-319-50093-5.
Chefaoui, R., C. Duarte and E. Serrao, 2018: Dramatic loss of seagrass habitat under projected climate change in the Mediterranean Sea. *Global Change Biology*, 24(10), 4919-4928, doi:10.1111/gcb.14401.
Cheung, W., J. Bruggeman and M. Butenschon, 2018: Chapter 4: Projected changes in global and national potential marine fisheries catch under climate change scenarios in the twenty-first century. In: *Impacts of climate change on fisheries and aquaculture: Synthesis of current knowledge, adaptation and mitigation options* [Barange, M., T.

Bahri, M. C. M. Beveridge, K. L. Cochrane, S. Funge-Smith and F. Poulain (eds.)]. Food and Agriculture Oranization of the United Nations, Rome, Italy, pp. 63-86.
Chou, S. C. et al., 2020: Downscaling projections of climate change in Sao Tome and Principe Islands, Africa. *Climate Dynamics*, 54(9-10), 4021-4042, doi:10.1007/s00382-020-05212-7.
CIMH, CWWA, CARDI and CDEMA, 2019: Sectoral Early Warning Information Systems across Climate Timescales (EWISACTs) Roadmap and Plan of Action (RPA) 2020-2030. Available at: https://rcc.cimh.edu.bb/.
Cinner, J. et al., 2016: A framework for understanding climate change impacts on coral reef social–ecological systems. *Regional Environmental Change*, 16(4), 1133-1146, doi:10.1007/s10113-015-0832-z.
Clifford, M., S. Ali and K. Matsubae, 2019: Mining, land restoration and sustainable development in isolated islands: An industrial ecology perspective on extractive transitions on Nauru. *Ambio*, 48(4), 397-408, doi:10.1007/s13280-018-1075-2.
Cole, P. and G. Banks, 2017: Renewable energy programmes in the South Pacific – Are these a solution to dependency? *Energy Policy*, 110, 500-508, doi:10.1016/j.enpol.2017.08.048.
Collier, C. et al., 2017: Optimum Temperatures for Net Primary Productivity of Three Tropical Seagrass Species. *Frontiers in Plant Science*, 8, 1446, doi:10.3389/fpls.2017.01446.
Connell, J., 2013: *Islands at Risk? Environments, Economies, and Contemporary Change*. Edward Elgar, Cheltenham.
Connell, J., 2015: Vulnerable Islands: Climate Change, Tectonic Change, and Changing Livelihoods in the Western Pacific. *The Contemporary Pacific*, 27(1), 1-36.
Connell, J., 2016: Last days in the Carteret Islands? Climate change, livelihoods and migration on coral atolls. *Asia Pacific Viewpoint*, 57(1), 3-15, doi:10.1111/apv.12118.
Conway, D. and J. Mustelin, 2014: Strategies for improving adaptation practice in developing countries. *Nature Climate Change*, 4(5), 339-342, doi:10.1038/nclimate2199.
Cornwall, C. E. et al., 2021: Global declines in coral reef calcium carbonate production under ocean acidification and warming. *PNAS*, 118(21), doi:10.1073/pnas.2015265118.
Costa, M., E. Macedo and E. Siegle, 2019: Wave refraction and reef island stability under rising sea level. *Global and Planetary Change*, 172, 256-267, doi:10.1016/j.gloplacha.2018.10.015.
Cowburn, B., M. Samoilys and D. Obura, 2018: The current status of coral reefs and their vulnerability to climate change and multiple human stresses in the Comoros Archipelago, Western Indian Ocean. *Marine Pollution Bulletin*, 133, 956-969, doi:10.1016/j.marpolbul.2018.04.065.
Cox, J. et al., 2018: Disaster, Divine Judgment, and Original Sin: Christian Interpretations of Tropical Cyclone Winston and Climate Change in Fiji. *The Contemporary Pacific*, 30(2), 380-410, doi:10.1353/cp.2018.0032.
Cramer, W. et al., 2018: Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change*, 8(11), 972-980, doi:10.1038/s41558-018-0299-2.
Crichton, R. and M. Esteban, 2018: Limits to Coastal Adaptation in Samoa: Insights and Experiences. In: *Limits to Climate Change Adaptation* [Filho, W. L. and J. Nalau (eds.)]. Springer, Cham, Switzerland, pp. 283-300. ISBN 978-3-319-64598-8.
Crichton, R. N., M. Esteban and M. Onuki, 2020: Understanding the preferences of rural communities for adaptation to 21st-century sea-level rise: A case study from the Samoan islands. *Climate Risk Management*, 30, doi:10.1016/j.crm.2020.100254.
Cruz, J. and C. Andrade, 2017: Groundwater salinization in Graciosa and Pico islands (Azores archipelago, Portugal): processes and impacts. *Journal of Hydrology: Regional Studies*, 12, 69-87, doi:10.1016/j.ejrh.2017.04.003.
Curnick, D. et al., 2019: The value of small mangrove patches. *Science*, 363(6424), doi:10.1126/science.aaw0809.
Currenti, R. et al., 2019: Adaptation to Climate Change in an Interior Pacific Island Village: a Case Study of Nawairuku, Ra, Fiji. *Human Ecology*, 47(1), 65-80, doi:10.1007/s10745-019-0049-8.
Curtain, R. and M. Dornan, 2019: *A pressure release valve? Migration and climate change in Kiribati, Nauru and Tuvalu*. Australian National University.
Cuvillier, A. et al., 2017: Causes of seasonal and decadal variability in a tropical seagrass seascape (Reunion Island, south western Indian Ocean). *Estuarine, Coastal and Shelf Science*, 184, 90-101, doi:10.1016/j.ecss.2016.10.046.
Cvitanovic, C. et al., 2016: Linking adaptation science to action to build food secure Pacific Island communities. *Climate Risk Management*, 11, 53-62, doi:10.1016/j.crm.2016.01.003.
Cvitanovic, C. et al., 2019: Maximising the benefits of participatory climate adaptation research by understanding and managing the associated challenges and risks. *Environmental Science & Policy*, 94, 20-31, doi:10.1016/j.envsci.2018.12.028.
de Beurs, K., N. McThompson, B. Owsley and G. Henebry, 2019: Hurricane damage detection on four major Caribbean islands. *Remote Sensing of Environment*, 229, 1-13, doi:10.1016/j.rse.2019.04.028.
De Ramon N'Yeurt, A. and V. Iese, 2014: The proliferating brown alga Sargassum polycystum in Tuvalu, South Pacific: assessment of the bloom and applications to local agriculture and sustainable energy. *Journal of Applied Phycology*, 27(5), 2037-2045, doi:10.1007/s10811-014-0435-y.
de Scally, F., 2014: Evaluation of storm surge risk: A case study from Rarotonga, Cook Islands. *International Journal of Disaster Risk Reduction*, 7, 9-27, doi:10.1016/j.ijdrr.2013.12.002.
De Souza, R. and J. Clarke, 2018: Chapter 11: Advancing Coastal Climate Resilience: Inclusive Data and Decision-Making for Small Island Communities. In: *Resilience: The Science of Adpatation to Climate Change* [Zommers, Z. and K. Alverson (eds.)]. Elsevier, pp. 143-150.

Delevaux, J. M. S. et al., 2018: A linked land-sea modeling framework to inform ridge-to-reef management in high oceanic islands. *PLoS One*, 13(3), e0193230, doi:10.1371/journal.pone.0193230.
Dey, M. et al., 2016: Economic impact of climate change and climate change adaptation strategies for fisheries sector in Solomon Islands: Implication for food security. *Marine Policy*, 67, 171-178, doi:10.1016/j.marpol.2016.01.004.
Di Falco, S. and S. Sharma, 2018: Investing in Climate Change Adaptation: Motivations and Green Incentives in the Fiji Islands. *Ecological Economics*, 154, 394-408, doi:10.1016/j.ecolecon.2018.08.015.
Di Falco, S. and S. Sharma-Khushal, 2019: Cognitive drivers, and the effect of information on climate change adaptive behaviour in Fiji Islands. *Environmental Science & Policy*, 92, 245-254, doi:10.1016/j.envsci.2018.11.019.
Donner, S., 2015: The legacy of migration in response to climate stress: learning from the Gilbertese resettlement in the Solomon Islands. *Natural Resources Forum*, 39(3-4), 191-201, doi:10.1111/1477-8947.12082.
Donner, S. and S. Webber, 2014: Obstacles to climate change adaptation decisions: a case study of sea-level rise and coastal protection measures in Kiribati. *Sustainability Science*, 9(3), 331-345, doi:10.1007/s11625-014-0242-z.
Donner, S. D., G. J. M. Rickbeil and S. F. Heron, 2017: A new, high-resolution global mass coral bleaching database. *PLoS One*, 12(4), e0175490, doi:10.1371/journal.pone.0175490.
Dookie, D., M. Enenkel and J. Spence, 2019: From science to science-based: Using state-of-the-art climate information to strengthen DRR in Small Island States. In: *Strengthening disaster resilience in small states: Commonwealth perspectives* [Khonje, W. and T. Mitchell (eds.)]. Commonwealth Secretariat, London, UK, pp. 13-41.
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, doi:10.1016/j.rser.2013.12.037.
Doswald, N. et al., 2014: Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base. *Climate and Development*, 6(2), 185-201, doi:10.1080/17565529.2013.867247.
Douglass, K. and J. Cooper, 2020: Archaeology, environmental justice, and climate change on islands of the Caribbean and southwestern Indian Ocean. *PNAS*, 117(15), 8254-8262, doi:10.1073/pnas.1914211117.
Drinkall, S. et al., 2019: Migration with Dignity: A case study on the livelihood transitions of Micronesians to Portland and Salem, Oregon. *Journal of Disaster Research*, 14(9), 1267-1276, doi:10.20965/jdr.2019.p1267.
Duarte, B. et al., 2018: Climate Change Impacts on Seagrass Meadows and Macroalgal Forests: An Integrative Perspective on Acclimation and Adaptation Potential. *Frontiers in Marine Science*, 5, doi:10.3389/fmars.2018.00190.
Ducrocq, V., P. Drobinski, S. Gualdi and P. Raimbault, 2016: Sub-chapter 1.2.1: The water cycle in the Mediterranean. In: *The Mediterranean region under climate change: A scientific update*. IRD Editions, Marseille, France. ISBN 9782709922203.
Duijndam, S. et al., 2020: Valuing a Caribbean coastal lagoon using the choice experiment method: The case of the Simpson Bay Lagoon, Saint Martin. *Journal for Nature Conservation*, 56, doi:10.1016/j.jnc.2020.125845.
Dunn, D. et al., 2018: A strategy for the conservation of biodiversity on mid-ocean ridges from deep-sea mining. *Science Advances*, 4, doi:10.1126/sciadv.aar4313.
Duvat, V., 2009: Beach erosion management in Small Island Developing States: Indian Ocean case studies. In: *Coastal Processes*, pp. 149-160, doi:10.2495/cp090141.
Duvat, V., 2013: Coastal protection structures in Tarawa Atoll, Republic of Kiribati. *Sustainability Science*, 8(3), 363-379, doi:10.1007/s11625-013-0205-9.
Duvat, V., A. Anisimov and A. Magnan, 2020a: Assessment of coastal risk reduction and adaptation-labelled responses in Mauritius Island (Indian Ocean). *Regional Environmental Change*, 20(110), doi:10.1007/s10113-020-01699-2.
Duvat, V. and A. Magnan, 2019a: Rapid human-driven undermining of atoll island capacity to adjust to ocean climate-related pressures. *Scientific Reports*, 9(15129), doi:10.1038/s41598-019-51468-3.
Duvat, V. et al., 2016: Assessing the impacts of and resilience to Tropical Cyclone Bejisa, Reunion Island (Indian Ocean). *Natural Hazards*, 83(1), 601-640, doi:10.1007/s11069-016-2338-5.
Duvat, V. et al., 2017a: Trajectories of exposure and vulnerability of small islands to climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 8(6), doi:10.1002/wcc.478.
Duvat, V. and A. K. Magnan, 2019b: Lessons learnt from coastal risks governance on Reunion Island, Indian Ocean, France. In: *Facing Hydrometeorological extremes events: a governance issue* [La Jeunesse, I. and C. Larrue (eds.)]. Wiley-Blackwell. ISBN 978-1-119-38354-3.
Duvat, V. et al., 2019a: High human influence on beach response to tropical cyclones in small islands: Saint-Martin Island, Lesser Antilles. *Geomorphology*, 325, 70-91, doi:10.1016/j.geomorph.2018.09.029.
Duvat, V. et al., 2020b: Contribution of moderate climate events to atoll island building (Fakarava Atoll, French Polynesia). *Geomorphology*, 354(107057), doi:10.1016/j.geomorph.2020.107057.
Duvat, V., B. Salvat and C. Salmon, 2017b: Drivers of shoreline change in atoll reef islands of the Tuamotu Archipelago, French Polynesia. *Global and Planetary Change*, 158, 134-154, doi:10.1016/j.gloplacha.2017.09.016.
Duvat, V., N. Volto and C. Salmon, 2017c: Impacts of category 5 tropical cyclone Fantala (April 2016) on Farquhar Atoll, Seychelles Islands, Indian Ocean. *Geomorphology*, 298, 41-62, doi:10.1016/j.geomorph.2017.09.022.
Duvat, V. K. E., 2018: A global assessment of atoll island planform changes over the past decades. *Wiley Interdisciplinary Reviews: Climate Change*, 10(1), doi:10.1002/wcc.557.
Duvat, V. K. E. et al., 2021a: Risks to future atoll habitability from climate-driven environmental changes. *WIREs Climate Change*, doi:10.1002/wcc.700.

Duvat, V. K. E. et al., 2019b: Taking control of human-induced destabilisation of atoll islands: lessons learnt from the Tuamotu Archipelago, French Polynesia. *Sustainability Science*, doi:10.1007/s11625-019-00722-8.
Duvat, V. K. E. et al., 2021b: Understanding interlinkages between long-term trajectory of exposure and vulnerability, path dependency and cascading impacts of disasters in Saint-Martin (Caribbean). *Global Environmental Change*, 67, doi:10.1016/j.gloenvcha.2021.102236.
Ebi, K. et al., 2018: Health risks of warming of 1.5 °C, 2 °C, and higher, above pre-industrial temperatures. *Environmental Research Letters*, 13(6), doi:10.1088/1748-9326/aac4bd.
Eckstein, D., M. Hutfils and M. Winges, 2018: *Who Suffers Most from Extreme Weather Events? Weather-related Loss Events in 2017 and 1998 to 2017*. Germanwatch, Germany.
Elders from Atafu Atoll, 2012: *Echoes at Fishermen's Rock: Traditional Tokelau fishing* [Hooper, A. and I. Tinielu (eds.)]. Knowledges of Nature 4, UNESCO, Paris, 120 pp.
Elliff, C. and I. Silva, 2017: Coral reefs as the first line of defense: Shoreline protection in face of climate change. *Marine Environment Research*, 127, 148-154, doi:10.1016/j.marenvres.2017.03.007.
Ellison, J., 1993: Mangrove Retreat with Rising Sea-level, Bermuda. *Estuarine, Coastal and Shelf Science*, 37, 75-87, doi:10.1006/ecss.1993.1042.
Ellison, J., 2005: Holocene palynology and sea-level change in two estuaries in Southern Irian Jaya. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 220(3-4), 291-309, doi:10.1016/j.palaeo.2005.01.008.
Ellison, J. and P. Strickland, 2015: Establishing relative sea level trends where a coast lacks a long term tide gauge. *Mitigation and Adaptation Strategies for Global Change*, 20(7), 1211-1227, doi:10.1007/s11027-013-9534-3.
Ellison, J. C., 2018: Pacific Island Beaches: Values, Threats and Rehabilitation. In: *Beach Management Tools - Concepts, Methodologies and Case Studies* [Botero, C., O. Cervantes and C. Finkl (eds.)]. Springer, Cham, Switzerland, pp. 679-700. ISBN 978-3-319-58303-7.
Enríquez, A. et al., 2017: Changes in beach shoreline due to sea level rise and waves under climate change scenarios: application to the Balearic Islands (western Mediterranean). *Natural Hazards and Earth System Sciences*, 17(7), 1075-1089, doi:10.5194/nhess-17-1075-2017.
Enríquez-de-Salamanca, Á., 2018: Vulnerability reduction and adaptation to climate change through watershed management in St. Vincent and the Grenadines. *GeoJournal*, 84(4), 1107-1119, doi:10.1007/s10708-018-9914-z.
Eppinga, M. and C. Pucko, 2018: The impact of hurricanse Irma and Maria on the forest ecosystems of Saba and St. Eustatius, north Caribbean. *Biotropica*, 50(5), 723-728, doi:10.1111/btp.12600.
Erauskin-Extramiana, M. et al., 2019: Large-scale distribution of tuna species in a warming ocean. *Global Change Biology*, 25(6), 2043-2060, doi:10.1111/gcb.14630.
Esteban, M. et al., 2019: Adaptation to sea level rise on low coral islands: Lessons from recent events. *Ocean & Coastal Management*, 168, 35-40, doi:10.1016/j.ocecoaman.2018.10.031.
Esteban, M. et al., 2020: Adaptation to sea level rise: Learning from present examples of land subsidence. *Ocean & Coastal Management*, 189, doi:10.1016/j.ocecoaman.2019.104852.
Etongo, D., 2019: Climate Change Adaptation in Seychelles: Actors, Actions, Barriers, Strategies for Improvement. *Seychelles Research Journal*, 1(2), 43-66.
Fabian, R., M. Beck and D. Potts, 2013: *Reef Restoration for Coastal Defense: A Review*. University of California, Santa Cruz, USA.
Fakhruddin, S., M. Babel and A. Kawasaki, 2015: Assessing the vulnerability of infrastructure to climate change on the Islands of Samoa. *Natural Hazards and Earth System Sciences*, 15(6), 1343-1356, doi:10.5194/nhess-15-1343-2015.
Falanruw, M., 2018: Canaries of Civilization: Small Island Vulnerability, Past Adaptations and Sea-Level Rise. In: *Indigenous Knowledge for Climate Change Assessment and Adaptation* [Nakashima, D., I. Krupnik and J. Rubis (eds.)]. Cambridge University Press, UNESCO, Cambridge, pp. 247-253. ISBN 9781316481066.
Falcon, W. and D. Hansen, 2018: Island rewilding with giant tortoises in an era of climate change. *Philosophical Transactions Royal Society B*, 373(1761), doi:10.1098/rstb.2017.0442.
FAO, 2016: *Drought characteristics and management in the Caribbean*. FAO Water Reports, 42, FAO, Rome.
Farbotko, C., 2018: Voluntary immobility: indigenous voices in the Pacific. *Forced Migration Reviews*, 57, 81-83.
Feng, Y. et al., 2018: Rapid remote sensing assessment of impacts from Hurricane Maria on forests of Puerto Rico. *PeerJ Preprints*, doi:10.7287/peerj.preprints.26597v1.
Ferdinand, M., 2018: Subnational climate justice for the French Outre-mer: postcolonial politics and geography of an epistemic shift. *Island Studies Journal*, 13(1), 119-134, doi:10.24043/isj.49.
Ferrario, F. et al., 2014: The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. *Nature Communications*, 5, 3794, doi:10.1038/ncomms4794.
Ferre, I. et al., 2019: Hurricane Maria's Impact on Punta Santiago, Puerto Rico: Community Needs and Mental Health Assessment Six Months Postimpact. *Disaster Medicine and Public Health Preparedness*, 13(1), 18-23, doi:10.1017/dmp.2018.103.
Ferreira, M. et al., 2016: Effects of climate change on the distribution of indigenous species in oceanic islands (Azores). *Climatic Change*, 138(3-4), 603-615, doi:10.1007/s10584-016-1754-6.
Fickert, T., 2018: Better Resilient than Resistant—Regeneration Dynamics of Storm-Disturbed Mangrove Forests on the Bay Island of Guanaja (Honduras) during the First Two Decades after Hurricane Mitch (October 1998). *Diversity*, 10(1), doi:10.3390/d10010008.

Filho, W. L. et al., 2020: Reviewing the role of ecosystems services in the sustainability of the urban environment: A multi-country analysis. *Journal of Cleaner Production*, 262, doi:10.1016/j.jclepro.2020.121338.
Filho, W. L. et al., 2019: Climate Change, Health and Mosquito-Borne Diseases: Trends and Implications to the Pacific Region. *International Journal of Environmental Research and Public Health*, 16(24), doi:10.3390/ijerph16245114.
Finucane, M. L. and V. W. Keener, 2015: Understanding the climate-sensitive decisions and information needs of island communities. *Journal of the Indian Ocean Region*, 11(1), 110-120, doi:10.1080/19480881.2015.1021181.
Fish, M. R. et al., 2005: Predicting the Impact of Sea-Level Rise on Caribbean Sea Turtle Nesting Habitat. *Conservation Biology*, 19(2), 482-491, doi:10.1111/j.1523-1739.2005.00146.x.
Fitzpatrick, S. M., M. Kappers and Q. Kaye, 2006: Coastal Erosion and Site Destruction on Carriacou, West Indies. *Journal of Field Archaeology*, 31(3), 251-262, doi:10.1179/009346906791071954.
Fleming, L. et al., 2019: Urban and rural sanitation in the Solomon Islands: How resilient are these to extreme weather events? *Science of the Total Environment*, 683, 331-340, doi:10.1016/j.scitotenv.2019.05.253.
Foley, A., 2018: Climate impact assessment and "islandness". *International Journal of Climate Change Strategies and Management*, 10(2), 289-302, doi:10.1108/ijccsm-06-2017-0142.
Ford, M., 2012: Shoreline Changes on an Urban Atoll in the Central Pacific Ocean: Majuro Atoll, Marshall Islands. *Journal of Coastal Research*, 28, 11-22, doi:10.2112/jcoastres-d-11-00008.1.
Ford, M. and P. Kench, 2016: Spatiotemporal variability of typhoon impacts and relaxation intervals on Jaluit Atoll, Marshall Islands. *Geology*, 44(2), 159-162, doi:10.1130/g37402.1.
Ford, M., M. Merrifield and J. Becker, 2018: Inundation of a low-lying urban atoll island: Majuro, Marshall Islands. *Natural Hazards*, 91(3), 1273-1297, doi:10.1007/s11069-018-3183-5.
Förster, J., E. McLeod, M. Bruton-Adams and H. Wittmer, 2019: Climate Change Impacts on Small Island States: Ecosystem Services Risks and Opportunities. In: *Atlas of Ecosystem Services* [Schroter, M. (ed.)], pp. 353-359. ISBN 978-3-319-96228-3.
Fortini, L. et al., 2015: Large-Scale Range Collapse of Hawaiian Forest Birds under Climate Change and the Need for 21st Century Conservation Options [corrected]. *PLoS One*, 10(10), e0140389, doi:10.1371/journal.pone.0140389.
Fox, M. D. et al., 2019: Limited coral mortality following acute thermal stress and widespread bleaching on Palmyra Atoll, central Pacific. *Coral Reefs*, 38(4), 701-712, doi:10.1007/s00338-019-01796-7.
Franks, J. S., D. R. Johnson and D. S. Ko, 2016: Pelagic Sargassum in the Tropical North Atlantic. *Gulf and Caribbean Research*, 27(1), doi:10.18785/gcr.2701.08.
Frauendorf, T. C. et al., 2020: Using a space-for-time substitution approach to predict the effects of climate change on nutrient cycling in tropical island stream ecosystems. *Limnology and Oceanography*, 65(12), 3114-3127, doi:10.1002/lno.11577.
Frazier, A. and L. Brewington, 2019: Current Changes in Alpine Ecosystems of Pacific Islands. *Encyclopedia of the World's Biomes*, 607-619, doi:10.1016/B978-0-12-409548-9.11881-0.
Friess, D., 2016: Ecosystem Services and Disservices of Mangrove Forests: Insights from Historical Colonial Observations. *Forests*, 7(183), doi:10.3390/f7090183.
Fuentes, M. M. P. B., C. J. Limpus and M. Hamann, 2011: Vulnerability of sea turtle nesting grounds to climate change. *Global Change Biology*, 17(1), 140-153, doi:10.1111/j.1365-2486.2010.02192.x.
Gahman, L. and G. Thongs, 2020: Development justice, a proposal: Reckoning with disaster, catastrophe, and climate change in the Caribbean. *Transactions of the Institute of British Geographers*, doi:10.1111/tran.12369.
Gaillard, J. et al., 2017: Beyond men and women: a critical perspective on gender and disaster. *Disasters*, 41(3), 429-447, doi:10.1111/disa.12209.
Gamble, D., D. Burrell, J. Popke and S. Curtis, 2017: Contextual analysis of dynamic drought perception among small farmers in Jamaica. *Climate Research*, 74(2), 109-120, doi:10.3354/cr01490.
Garcin, M. et al., 2016: Lagoon islets as indicators of recent environmental changes in the South Pacific – The New Caledonian example. *Continental Shelf Research*, 122, 120-140, doi:10.1016/j.csr.2016.03.025.
Gattuso, J. et al., 2015: Contrasting futures for ocean and society from different anthropogenic CO2 emissions scenarios. *Science*, 349(6243), aac4722, doi:10.1126/science.aac4722.
Gero, A. et al., 2015: Disasters and climate change in the Pacific: adaptive capacity of humanitarian response organizations. *Climate and Development*, 7(1), 35-46, doi:10.1080/17565529.2014.899888.
Gharbaoui, D. and J. Blocher, 2016: The Reason Land Matters: Relocation as Adaptation to Climate Change in Fiji Islands. In: *Migration, Risk Management and Climate Change: Evidence and Policy Responses* [Milan, A., B. Schraven, K. Warner and N. Cascone (eds.)]. Springer, Cham, pp. 149-173. ISBN 978-3-319-42920-5.
Giardino, A., K. Nederhoff and M. Vousdoukas, 2018: Coastal hazard risk assessment for small islands: assessing the impact of climate change and disaster reduction measures on Ebeye (Marshall Islands). *Regional Environmental Change*, 18(8), 2237-2248, doi:10.1007/s10113-018-1353-3.
Gibson, K., N. Haslam and I. Kaplan, 2019: Distressing encounters in the context of climate change: Idioms of distress, determinants, and responses to distress in Tuvalu. *Transcultural Psychiatry*, 56(4), 667-696, doi:10.1177/1363461519847057.
Gibson, K. E., J. Barnett, N. Haslam and I. Kaplan, 2020: The mental health impacts of climate change: Findings from a Pacific Island atoll nation. *Journal of Anxiety Disorders*, 73, doi:10.1016/j.janxdis.2020.102237.

Giffin, A. et al., 2020: Marine and coastal ecosystem-based adaptation in Asia and Oceania: review of approaches and integration with marine spatial planning. *Pacific Conservation Biology*, doi:10.1071/pc20025.
Gilman, E., J. Ellison, I. Sauni and S. Tuaumu, 2007: Trends in surface elevations of American Samoa mangroves. *Wetlands Ecology and Management*, 15(5), 391-404, doi:10.1007/s11273-007-9038-6.
Gingerich, S., C. Voss and A. Johnson, 2017: Seawater-flooding events and impact on freshwater lenses of low-lying islands: Controlling factors, basic management and mitigation. *Journal of Hydrology*, 551, 676-688, doi:10.1016/j.jhydrol.2017.03.001.
Gischler, E. and R. Kikinger, 2006: Effects of the tsunami of 26 December 2004 on Rasdhoo and Northern Ari Atolls, Maldives. *Atoll Research Bulletin*, 561.
Gohar, A., A. Cashman and F. Ward, 2019: Managing food and water security in Small Island States: New evidence from economic modelling of climate stressed groundwater resources. *Journal of Hydrology*, 569, 239-251, doi:10.1016/j.jhydrol.2018.12.008.
Golbuu, Y. et al., 2007: Palau's coral reefs show differential habitat recovery following the 1998-bleaching event. *Coral Reefs*, 26(2), 319-332, doi:10.1007/s00338-007-0200-7.
González-Alemán, J. J. et al., 2019: Potential Increase in Hazard From Mediterranean Hurricane Activity With Global Warming. *Geophysical Research Letters*, 46(3), 1754-1764, doi:10.1029/2018gl081253.
Goodman, J. et al., 2012: Differential response to soil salinity in endangered key tree cactus: implications for survival in a changing climate. *PLoS One*, 7(3), e32528, doi:10.1371/journal.pone.0032528.
Goudie, A. S., 2014: Desert dust and human health disorders. *Environmental International*, 63, 101-113, doi:10.1016/j.envint.2013.10.011.
Goudie, A. S., 2020: Dust storms and human health. In: *Extreme Weather Events and Human Health: International Case Studies* [Akhtar, R. (ed.)]. Springer, Switzerland. ISBN 978-3-030-23772-1.
Goulding, W., P. Moss and C. McAlpine, 2016: Cascading effects of cyclones on the biodiversity of Southwest Pacific islands. *Biological Conservation*, 193, 143-152, doi:10.1016/j.biocon.2015.11.022.
Gourlie, D. et al., 2018: Performing "A New Song": Suggested Considerations for Drafting Effective Coastal Fisheries Legislation Under Climate Change. *Marine Policy*, 88, 342-349, doi:10.1016/j.marpol.2017.06.012.
Gracia, A., N. Rangel-Buitrago, J. A. Oakley and A. T. Williams, 2018: Use of ecosystems in coastal erosion management. *Ocean & Coastal Management*, 156, 277-289, doi:10.1016/j.ocecoaman.2017.07.009.
Grady, A. et al., 2013: The influence of sea level rise and changes in fringing reef morphology on gradients in alongshore sediment transport. *Geophysical Research Letters*, 40(12), 3096-3101, doi:10.1002/grl.50577.
Graham, N. et al., 2015: Predicting climate-driven regime shifts versus rebound potential in coral reefs. *Nature*, 518(7537), 94-97, doi:10.1038/nature14140.
Granderson, A., 2017: The Role of Traditional Knowledge in Building Adaptive Capacity for Climate Change: Perspectives from Vanuatu. *Weather, Climate, and Society*, 9(3), 545-561, doi:10.1175/wcas-d-16-0094.1.
Group, W. B., 2015: CIF Pilot Program for Climate Resilience.
Guido, Z. et al., 2018: The stresses and dynamics of smallholder coffee systems in Jamaica's Blue Mountains: a case for the potential role of climate services. *Climatic Change*, 147(1-2), 253-266, doi:10.1007/s10584-017-2125-7.
Guilyardi, E. et al., 2016: Fourth CLIVAR Workshop on the Evaluation of ENSO Processes in Climate Models: ENSO in a Changing Climate. *Bulletin of the American Meteorological Society*, 97(5), 817-820, doi:10.1175/bams-d-15-00287.1.
Ha'apio, M. O., R. Gonzalez and M. Wairiu, 2019: Is there any chance for the poor to cope with extreme environmental events? Two case studies in the Solomon Islands. *World Development*, 122, 514-524, doi:10.1016/j.worlddev.2019.06.023.
Habel, S., C. H. Fletcher, T. R. Anderson and P. R. Thompson, 2020: Sea-Level Rise Induced Multi-Mechanism Flooding and Contribution to Urban Infrastructure Failure. *Scientific Reports*, 10(1), 3796, doi:10.1038/s41598-020-60762-4.
Hagedoorn, L. et al., 2019: Community-based adaptation to climate change in small island developing states: an analysis of the role of social capital. *Climate and Development*, 1-12, doi:10.1080/17565529.2018.1562869.
Haines, S., 2019: Managing expectations: articulating expertise in climate services for agriculture in Belize. *Climate Change*, 157, 43-59, doi:10.1007/s10584-018-2357-1.
Hambleton, I. R., S. M. Jeyaseelan and M. M. Murphy, 2020: COVID-19 in the Caribbean small island developing states: lessons learnt from extreme weather events. *The Lancet Global Health*, 8(9), e1114-e1115, doi:10.1016/s2214-109x(20)30291-6.
Hampton, M. P. and J. Jeyacheya, 2020: Tourism-Dependent Small Islands, Inclusive Growth, and the Blue Economy. *One Earth*, 2(1), 8-10, doi:10.1016/j.oneear.2019.12.017.
Handmer, J. and H. Iveson, 2017: Cyclone Pam in Vanuatu: learning from the low death toll. *Australian Journal of Emergency Management*, 32(2), 60-65.
Handmer, J. and J. Nalau, 2019: Understanding Loss and Damage in Pacific Small Island Developing States. In: *Loss and Damage from Climate Change: Concepts, Methods and Policy Options* [Mechler, R., L. Bouwer, T. Schinko, S. Surminski and J. Linnerooth-Bayer (eds.)]. Springer International Publishing, pp. 365-381. ISBN 978-3-319-72025-8.
Hanich, Q. et al., 2018: Small-scale fisheries under climate change in the Pacific Islands region. *Marine Policy*, 88, 279-284, doi:10.1016/j.marpol.2017.11.011.

Hansen, G. and W. Cramer, 2015: Global distribution of observed climate change impacts. *Nature Climate Change*, 5(3), 182-185, doi:10.1038/nclimate2529.
Harris, D. et al., 2018: Coral reef structural complexity provides important coastal protection from waves under rising sea levels. *Science Advances*, 4, doi:eaao4350.
Harter, D. et al., 2015: Impacts of global climate change on the floras of oceanic islands – Projections, implications and current knowledge. *Perspectives in Plant Ecology, Evolution and Systematics*, 17(2), 160-183, doi:10.1016/j.ppees.2015.01.003.
Hassanali, K., 2020: CARICOM and the blue economy – Multiple understandings and their implications for global engagement. *Marine Policy*, 120, doi:10.1016/j.marpol.2020.104137.
Hay, J., 2013: Small island developing states: coastal systems, global change and sustainability. *Sustainability Science*, 8(3), 309-326, doi:10.1007/s11625-013-0214-8.
Hay, J., V. Duvat and A. K. Magnan, 2019a: Trends in Vulnerability to Climate-related Hazards in the Pacific: Research, Understanding and Implications. In: *The Oxford Handbook of Planning for Climate Change Hazards* [Pfeffer, T., J. Smith and K. Ebi (eds.)]. Oxford University Press, New York.
Hay, J., P. Hartley and J. Roop, 2019b: Climate risk assessments and management options for redevelopment of the Parliamentary Complex in Samoa, South Pacific. *Weather and Climate Extremes*, 25, doi:10.1016/j.wace.2019.100214.
Haynes, E. et al., 2020: Food Sources and Dietary Quality in Small Island Developing States: Development of Methods and Policy Relevant Novel Survey Data from the Pacific and Caribbean. *Nutrients*, 12(11), doi:10.3390/nu12113350.
Hayward, B., D. H. Salili, L. L. Tupuana'i and J. Tualamali'i, 2019: It's not "too late": Learning from Pacific Small Island Developing States in a warming world. *WIREs Climate Change*, 11(1), doi:10.1002/wcc.612.
Hejnowicz, A., H. Kennedy, M. Rudd and M. Huxham, 2015: Harnessing the climate mitigation, conservation and poverty alleviation potential of seagrasses: prospects for developing blue carbon initiatives and payment for ecosystem service programmes. *Frontiers in Marine Science*, 2(32), doi:10.3389/fmars.2015.00032.
Heller, N. and E. Zavaleta, 2009: Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation*, 142(1), 14-32, doi:10.1016/j.biocon.2008.10.006.
Hellmann, J., J. Byers, B. Bierwagen and J. Dukes, 2008: Five potential consequences of climate change for invasive species. *Conservation Biology*, 22(3), 534-543, doi:10.1111/j.1523-1739.2008.00951.x.
Hemstock, S. et al., 2018: Professionalizing the "resilience" sector in the Pacific Islands Region: Formal education for capacity building. In: *A Critical Approach to Climate Change Adaptation: Discourses, Policies and Practices*. Routledge Advances in Climate Change Research, Routledge, UK. ISBN 978-1-13-805629-9.
Hermann, E. and W. Kempf, 2017: Climate Change and the Imagining of Migration: Emerging Discourses on Kiribati's Land Purchase in Fiji. *The Contemporary Pacific*, 29(2), 231-263, doi:10.1353/cp.2017.0030.
Hermes, J. et al., 2019: A Sustained Ocean Observing System in the Indian Ocean for Climate Related Scientific Knowledge and Societal Needs. *Frontiers in Marine Science*, 6, doi:10.3389/fmars.2019.00355.
Hernan, G. et al., 2017: Future warmer seas: increased stress and susceptibility to grazing in seedlings of a marine habitat-forming species. *Global Change Biology*, 23(11), 4530-4543, doi:10.1111/gcb.13768.
Hernandez-Delgado, E., 2015: The emerging threats of climate change on tropical coastal ecosystem services, public health, local economies and livelihood sustainability of small islands: Cumulative impacts and synergies. *Marine Pollution Bulletin*, 101(1), 5-28, doi:10.1016/j.marpolbul.2015.09.018.
Herrera, D. and T. Ault, 2017: Insights from a New High-Resolution Drought Atlas for the Caribbean Spanning 1950–2016. *Journal of Climate*, 30(19), 7801-7825, doi:10.1175/jcli-d-16-0838.1.
Hess, J. and I. Kelman, 2017: Tourism Industry Financing of Climate Change Adaptation: Exploring the Potential in Small Island Developing States. *Climate, Disaster and Development Journal*, 2(2), 34-45, doi:10.18783/cddj.v002.i02.a04.
Hickey, G. M. and N. Unwin, 2020: Addressing the triple burden of malnutrition in the time of COVID-19 and climate change in Small Island Developing States: what role for improved local food production? *Food Security*, 1-5, doi:10.1007/s12571-020-01066-3.
Hills, J., E. Michalena and K. Chalvatzis, 2018: Innovative Technology in the Pacific: Building Resilience for Vulnerable Communities. *Technological Forecasting and Social Change*, 129, 16-26, doi:10.1016/j.techfore.2018.01.008.
Hinkel, J. et al., 2018: The ability of societies to adapt to twenty-first-century sea-level rise. *Nature Climate Change*, 8(7), 570-578, doi:10.1038/s41558-018-0176-z.
Hino, M., C. Field and K. Mach, 2017: Managed retreat as a response to natural hazard risk. *Nature Climate Change*, 7(5), 364-370, doi:10.1038/nclimate3252.
Hiwasaki, L., E. Luna, Syamsidik and R. Shaw, 2014: Process for integrating local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation in coastal and small island communities. *International Journal of Disaster Risk Reduction*, 10, 15-27, doi:10.1016/j.ijdrr.2014.07.007.
Hoegh-Guldberg, O. et al., 2018: Impacts of 1.5°C Global Warming on Natural and Human Systems. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P.

Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Pan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield (eds.)].

Hoegh-Guldberg, O. et al., 2019: The human imperative of stabilizing global climate change at 1.5°C. *Science*, 365(6459), doi:10.1126/science.aaw6974.

Hoegh-Guldberg, O., E. Poloczanska, W. Skirving and S. Dove, 2017: Coral Reef Ecosystems under Climate Change and Ocean Acidification. *Frontiers in Marine Science*, 4, doi:10.3389/fmars.2017.00158.

Hoeke, R., K. McInnes and J. O'Grady, 2015: Wind and Wave Setup Contributions to Extreme Sea Levels at a Tropical High Island: A Stochastic Cyclone Simulation Study for Apia, Samoa. *Journal of Marine Science and Engineering*, 3(3), 1117-1135, doi:10.3390/jmse3031117.

Hoeke, R. K., H. Damlamian, J. Aucan and M. Wandres, 2021: Severe Flooding in the Atoll Nations of Tuvalu and Kiribati Triggered by a Distant Tropical Cyclone Pam. *Frontiers in Marine Science*, 7, doi:10.3389/fmars.2020.539646.

Hoeke, R. K. et al., 2013: Widespread inundation of Pacific islands triggered by distant-source wind-waves. *Global and Planetary Change*, 108, 128-138, doi:10.1016/j.gloplacha.2013.06.006.

Hof, A., M. Blazquez-Salom, M. Colom and A. Periz, 2014: Chapter 9: Challenges and Solutions for Urban-Tourist Water Supply on Mediterranean Tourist Islands: The Case of Majorca, Spain. In: *The Global Water System in the Anthropocene* [Bhaduri, A., J. Bogardi, J. Leentvaar and S. Marx (eds.)]. Springer, Charm.

Hofmann, R., 2014: Culturecide in changing Micronesian climates? About the unintenionality of climate change. *The International Journal of Human Rights*, 18(3), 336-349, doi:10.1080/13642987.2014.914707.

Hofmann, R., 2017: Experiencing environmental dynamics in Chuuk, Micronesia. In: *Environmental Transformations and Cultural Responses: Ontologies, Discourses, and Practices in Oceania* [Durr, E. and A. Pascht (eds.)]. Palgrave Macmillan, pp. 75-102.

Holding, S. et al., 2016: Groundwater vulnerability on small islands. *Nature Climate Change*, 6(12), 1100-1103, doi:10.1038/nclimate3128.

Hopley, D., S. Smithers and K. Parnell, 2007: *Geomorphology of the Great Barrier Reef: Development, Diversity and Change*. Cambridge University Press, Cambridge, UK. ISBN 9780511535543.

Hu, T. and R. Smith, 2018: The Impact of Hurricane Maria on the Vegetation of Dominica and Puerto Rico Using Multispectral Remote Sensing. *Remote Sensing*, 10(6), doi:10.3390/rs10060827.

Hughes, T. et al., 2018: Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science*, 359(6371), 80-83, doi:10.1126/science.aan8048.

Hughes, T. et al., 2017a: Coral reefs in the Anthropocene. *Nature*, 546(7656), 82-90, doi:10.1038/nature22901.

Hughes, T. et al., 2017b: Global warming and recurrent mass bleaching of corals. *Nature*, 543(7645), 373-377, doi:10.1038/nature21707.

Hulland, E. et al., 2019: Increase in Reported Cholera Cases in Haiti Following Hurricane Matthew: An Interrupted Time Series Model. *American Journal of Tropical Medicine and Hygiene*, 100(2), 368-373, doi:10.4269/ajtmh.17-0964.

Iese, V. et al., 2020: Agriculture Under a Changing Climate. In: *Climate Change and Impacts in the Pacific* [Kumar, L. (ed.)]. Springer, Cham, Cham, Switzerland, pp. 323-358. ISBN 978-3-030-32877-1.

Iese, V. et al., 2021: Historical and future drought impacts in the Pacific islands and atolls. *Climatic Change*, 166(1-2), doi:10.1007/s10584-021-03112-1.

IPBES, 2018: *The IPBES assessment report on land degradation and restoration* [Montanarella, L., R. Scholes and A. Brainich (eds.)]. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.

IPBES, 2019: *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* [Díaz, S., J. Settele, B. E.S., H. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. Brauman, S. Butchart, K. Chan, L. Garibaldi, K. Ichii, J. Liu, S. Subramanian, G. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. Shin, I. Visseren-Hamakers, K. Willis and C. Zayas (eds.)]. IPBES Secretariat, Bonn, Germany, 56 pp.

IPCC, 2018: *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the globalresponse to the threat of climate change, sustainable development, and efforts to eradicate poverty.* [Masson-Delmotte, V., P. Zhai, H. O. Portner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Pean, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield (eds.)].

IPCC, 2019: *Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H. O., D. Roberts, V. Masson-Delmotte, P. Zhai, Y. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)].

Islam, M. S. and E. Kieu, 2020: Tackling Regional Climate Change Impacts and Food Security Issues: A Critical Analysis across ASEAN, PIF, and SAARC. *Sustainability*, 12(3), doi:10.3390/su12030883.

Jackson, C., D. Bush and W. Neal, 2012: Documenting beach loss in front of seawalls in Puerto Rico: pitfalls of engineering a small Island nation shore. In: *Pitfalls of Shoreline Stabilization* [Cooper, J. A. G. and O. H. Pilkey (eds.)]. Springer, Netherlands.
Jamero, M. L. et al., 2017: Small-island communities in the Philippines prefer local measures to relocation in response to sea-level rise. *Nature Climate Change*, 7(8), 581-586, doi:10.1038/nclimate3344.
Janif, S. et al., 2016: Value of traditional oral narratives in building climate-change resilience: insights from rural communities in Fiji. *Ecology and Society*, 21(2), doi:10.5751/ES-08100-210207.
Jeanne, I. et al., 2018: Mapping a Plasmodium transmission spatial suitability index in Solomon Islands: a malaria monitoring and control tool. *Malaria Journal*, 17(1), 381, doi:10.1186/s12936-018-2521-0.
Jimenez-Ramos, R. et al., 2017: Global and local disturbances interact to modify seagrass palatability. *PLoS One*, 12(8), e0183256, doi:10.1371/journal.pone.0183256.
Johnston, I., 2014: Disaster management and climate change adaptation: a remote island perspective. *Disaster Prevention and Management*, 23(2), 123-137, doi:10.1108/dpm-06-2013-0096.
Johnston, I., 2015: Traditional warning signs of cyclones on remote islands in Fiji and Tonga. *Environmental Hazards*, 14(3), 210-223, doi:10.1080/17477891.2015.1046156.
Johnston, M. W. and S. J. Purkis, 2015: Hurricanes accelerated the Florida-Bahamas lionfish invasion. *Global Change Biology*, 21(6), 2249-2260, doi:10.1111/gcb.12874.
Jones, H. et al., 2016: Invasive mammal eradication on islands results in substantial conservation gains. *PNAS*, 113(15), 4033-4038, doi:10.1073/pnas.1521179113.
Jones, P. et al., 2015: Long-term trends in precipitation and temperature across the Caribbean. *International Journal of Climatology*, 36(9), 3314-3333, doi:10.1002/joc.4557.
Jones, R., 2019: Climate change and Indigenous Health Promotion. *Global Health Promotion*, 26(3_suppl), 73-81, doi:10.1177/1757975919829713.
Joseph, L. et al., 2019: Implications of Seagrass Ecosystem Degradation on Marine Resources and People's Livelihood: A Case Study from Komave Village, Fiji. *Asian Journal of Fisheries and Aquatic Research*, 2(3), 1-13, doi:10.9734/AJFAR/2018/v2i330011.
Jury, M. R., 2018: Characteristics and Meteorology of Atlantic Swells Reaching the Caribbean. *Journal of Coastal Research*, 342, 400-412, doi:10.2112/jcoastres-d-17-00029.1.
Kane, H. H. and C. H. Fletcher, 2020: Rethinking Reef Island Stability in Relation to Anthropogenic Sea Level Rise. *Earth's Future*, 8(10), doi:10.1029/2020ef001525.
Karlsson, M. and G. Hovelsrud, 2015: Local collective action: Adaptation to coastal erosion in the Monkey River Village, Belize. *Global Environmental Change*, 32, 96-107, doi:10.1016/j.gloenvcha.2015.03.002.
Karlsson, M. and E. McLean, 2020: Caribbean Small-Scale Fishers' Strategies for Extreme Weather Events: Lessons for Adaptive Capacity from the Dominican Republic and Belize. *Coastal Management*, 48(5), 456-480, doi:10.1080/08920753.2020.1795971.
Karnauskas, K., J. Donnelly and K. Anchukaitis, 2016: Future freshwater stress for island populations. *Nature Climate Change*, 6(7), 720-725, doi:10.1038/nclimate2987.
Karnauskas, K., C. Schleussner, J. Donnelly and K. Anchukaitis, 2018: Freshwater stress on small island developing states: population projections and aridity changes at 1.5 and 2 °C. *Regional Environmental Change*, 18(8), 2273-2282, doi:10.1007/s10113-018-1331-9.
Katircioglu, S., M. Cizreliogullari and S. Katircioglu, 2019: Estimating the role of climate changes on international tourist flows: evidence from Mediterranean Island States. *Environmental Science and Pollution Research*, 26(14), 14393-14399, doi:10.1007/s11356-019-04750-w.
Katovai, E., D. D. Katovai, W. Edwards and W. F. Laurance, 2015: Forest Structure, Plant Diversity and Local Endemism in a Highly Varied New Guinea Landscape. *Tropical Conservation Science*, 8(2), 284-300, doi:10.1177/194008291500800202.
Kauffman, J. B. and T. G. Cole, 2010: Micronesian Mangrove Forest Structure and Tree Responses to a Severe Typhoon. *Wetlands*, 30(6), 1077-1084, doi:10.1007/s13157-010-0114-y.
Kayanne, H. et al., 2016: Eco-geomorphic processes that maintain a small coral reef island: Ballast Island in the Ryukyu Islands, Japan. *Geomorphology*, 271, 84-93, doi:10.1016/j.geomorph.2016.07.021.
Keen, M. and J. Connell, 2019: Regionalism and Resilience? Meeting Urban Challenges in Pacific Island States. *Urban Policy and Research*, 37(3), 324-337, doi:10.1080/08111146.2019.1626710.
Keen, M., A. Schwarz and L. Wini-Simeon, 2018: Towards defining the Blue Economy: Practical lessons from pacific ocean governance. *Marine Policy*, 88, 333-341, doi:10.1016/j.marpol.2017.03.002.
Kelaher, B., M. Coleman and M. Bishop, 2018: Ocean warming, but not acidification, accelerates seagrass decomposition under near-future climate scenarios. *Marine Ecology Progress Series*, 605, 103-110, doi:10.3354/meps12762
Kelman, I., 2014: No change from climate change: vulnerability and small island developing states. *The Geographical Journal*, 180(2), 120-129, doi:10.1111/geoj.12019.
Kelman, I., 2015a: Difficult decisions: Migration from Small Island Developing States under climate change. *Earth's Future*, 3(4), 133-142, doi:10.1002/2014ef000278.
Kelman, I., 2015b: Disaster Risk Governance for Pacific Island Communities. *The Asia-Pacific Journal*, 13(48).

Kelman, I., 2018: Islandness within climate change narratives of small island developing states (SIDS). *Island Studies Journal*, 13(1), 149-166, doi:10.24043/isj.52.

Kelman, I. et al., 2017: Here and now: perceptions of Indian Ocean islanders on the climate change and migration nexus. *Geografiska Annaler: Series B, Human Geography*, 99(3), 284-303, doi:10.1080/04353684.2017.1353888.

Kench, P., 2012: Compromising Reef Island Shoreline Dynamics: Legacies of the Engineering Paradigm in the Maldives. In: *Pitfalls of Shoreline Stabilization: Selected Case Studies* [Cooper, J. and O. Pilkey (eds.)]. Springer, Cham, Switzerland, pp. 165-186. ISBN 978-94-007-4122-5.

Kench, P., M. Ford and S. Owen, 2018: Patterns of island change and persistence offer alternate adaptation pathways for atoll nations. *Nature Communications*, 9(1), 605, doi:10.1038/s41467-018-02954-1.

Kench, P. and T. Mann, 2017: Reef Island Evolution and Dynamics: Insights from the Indian and Pacific Oceans and Perspectives for the Spermonde Archipelago. *Frontiers in Marine Science*, 4, doi:10.3389/fmars.2017.00145.

Kench, P. et al., 2015: Coral islands defy sea-level rise over the past century: Records from a central Pacific atoll. *Geology*, 43(6), 515-518, doi:10.1130/g36555.1.

Kendrick, G. A. et al., 2019: A Systematic Review of How Multiple Stressors From an Extreme Event Drove Ecosystem-Wide Loss of Resilience in an Iconic Seagrass Community. *Frontiers in Marine Science*, 6, doi:10.3389/fmars.2019.00455.

Keppel, G., C. Morrison, J. Meyer and H. Boehmer, 2014: Isolated and vulnerable: the history and future of Pacific Island terrestrial biodiversity. *Pacific Conservation Biology*, 20(2).

Khan, A. and V. Amelie, 2015: Assessing climate change readiness in Seychelles: implications for ecosystem-based adaptation mainstreaming and marine spatial planning. *Regional Environmental Change*, 15(4), 721-733, doi:10.1007/s10113-014-0662-4.

Kibler, S. et al., 2015: Effects of ocean warming on growth and distribution of dinoflagellates associated with ciguatera fish poisoning in the Caribbean. *Ecological Modelling*, 316, 194-210, doi:10.1016/j.ecolmodel.2015.08.020.

Kiddle, G. et al., 2017: Unpacking the Pacific Urban Agenda: Resilience Challenges and Opportunities. *Sustainability*, 9(10), doi:10.3390/su9101878.

Kim, K. and L. Bui, 2019: Learning from Hurricane Maria: Island ports and supply chain resilience. *International Journal of Disaster Risk Reduction*, 39(101244), doi:10.1016/j.ijdrr.2019.101244.

Kim, R., A. Costello and D. Campbell-Lendrum, 2015: Climate change and health in Pacific island states. *Bulletin from the World Health Organization*, 93(12), 819, doi:10.2471/BLT.15.166199.

Kishore, N. et al., 2018: Mortality in Puerto Rico after Hurricane Maria. *New England Journal of Medicine*, 379(2), 162-170, doi:10.1056/NEJMsa1803972.

Klomp, J., 2017: Flooded with debt. *Journal of International Money and Finance*, 73, 93-103, doi:10.1016/j.jimonfin.2017.01.006.

Knutson, T. et al., 2019: Tropical Cyclones and Climate Change Assessment: Part I: Detection and Attribution. *Bulletin of the American Meteorological Society*, 100(10), 1987-2007, doi:10.1175/bams-d-18-0189.1.

Koester, A. et al., 2020: Early trajectories of benthic coral reef communities following the 2015/16 coral bleaching event at remote Aldabra Atoll, Seychelles. *Sci Rep*, 10(1), 17034, doi:10.1038/s41598-020-74077-x.

Koide, D. et al., 2017: An upward elevation shift of native and non-native vascular plants over 40 years on the island of Hawai'i. *Journal of Vegetation Science*, 28(5), 939-950, doi:10.1111/jvs.12549.

Kossin, J., K. Emanuel and S. Camargo, 2016: Past and Projected Changes in Western North Pacific Tropical Cyclone Exposure. *Journal of Climate*, 29(16), 5725-5739, doi:10.1175/jcli-d-16-0076.1.

Kossin, J., K. Knapp, T. Olander and C. Velden, 2020: Global increase in major tropical cyclone exceedance probability over the past four decades. *PNAS*, 117(22), 11975-11980, doi:10.1073/pnas.2021573117.

Kossin, J. P. et al., 2017: Extreme Storms. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume 1* [Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. Stewart and T. Maycock (eds.)]. U.S. Global Change Research Program, Washington D.C., USA, pp. 257-276.

Kotsinas, M., 2020: Climate (In)justice: An Intersectional Feminist Analysis of Disaster Management in Antigua and Barbuda in the Aftermath of Hurricane Irma. *Politikon: The IAPSS Journal of Political Science*, 47, 7-35, doi:10.22151/politikon.47.1.

Koutroulis, A. et al., 2016: Cross sectoral impacts on water availability at +2 °C and +3 °C for east Mediterranean island states: The case of Crete. *Journal of Hydrology*, 532, 16-28, doi:10.1016/j.jhydrol.2015.11.015.

Krauss, K. W. et al., 2010: Surface Elevation Change and Susceptibility of Different Mangrove Zones to Sea-Level Rise on Pacific High Islands of Micronesia. *Ecosystems*, 13(1), 129-143, doi:10.1007/s10021-009-9307-8.

Krushelnycky, P. D. et al., 2012: Climate-associated population declines reverse recovery and threaten future of an iconic high-elevation plant. *Global Change Biology*, 19(3), 911-922, doi:10.1111/gcb.12111.

Kuleshov, Y., P. Gregory, A. B. Watkins and R. J. B. Fawcett, 2020: Tropical cyclone early warnings for the regions of the Southern Hemisphere: strengthening resilience to tropical cyclones in small island developing states and least developed countries. *Natural Hazards*, 104(2), 1295-1313, doi:10.1007/s11069-020-04214-2.

Kuleshov, Y. et al., 2014: Extreme Weather and Climate Events and Their Impacts on Island Countries in the Western Pacific: Cyclones, Floods and Droughts. *Atmospheric and Climate Sciences*, 04(05), 803-818, doi:10.4236/acs.2014.45071.

Kulp, S. and B. Strauss, 2019: New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. *Nature Communications*, 10(4844), doi:10.1038/s41467-019-12808-z.

Kumar, L. et al., 2018: An indicative index of physical susceptibility of small islands to coastal erosion induced by climate change: an application to the Pacific islands. *Geomatics, Natural Hazards and Risk*, 9(1), 691-702, doi:10.1080/19475705.2018.1455749.
Kumar, L. et al., 2020: *Climate Change and Impacts in the Pacific*, 1 ed. [Kumar, L. (ed.)]. Springer, Berlin, 557 pp.
Kumar, L. and S. Taylor, 2015: Exposure of coastal built assets in the South Pacific to climate risks. *Nature Climate Change*, 5(11), 992-996, doi:10.1038/nclimate2702.
Kumar, L. and M. Tehrany, 2017: Climate change impacts on the threatened terrestrial vertebrates of the Pacific Islands. *Scientific Reports*, 7(5030), doi:10.1038/s41598-017-05034-4.
Kuruppu, N. and R. Willie, 2015: Barriers to reducing climate enhanced disaster risks in Least Developed Country-Small Islands through anticipatory adaptation. *Weather and Climate Extremes*, 7, 72-83, doi:10.1016/j.wace.2014.06.001.
Laczko, F. and E. Piguet, 2014: Regional Perspectives on Migration, the Environment and Climate Change. In: *People on the Move in a Changing Climate: The regional impact of environmental change on migration* [Piguet, E. and F. Laczko (eds.)]. Springer, Cham, Switzerland.
Lal, A. and B. Datta, 2019: Multi-objective groundwater management strategy under uncertainties for sustainable control of saltwater intrusion: Solution for an island country in the South Pacific. *Journal of Environmental Management*, 234, 115-130, doi:10.1016/j.jenvman.2018.12.054.
Lallo, C. H. O. et al., 2018: Characterizing heat stress on livestock using the temperature humidity index (THI)—prospects for a warmer Caribbean. *Regional Environmental Change*, 18(8), 2329-2340, doi:10.1007/s10113-018-1359-x.
Laloë, J.-O., N. Esteban, J. Berkel and G. C. Hays, 2016: Sand temperatures for nesting sea turtles in the Caribbean: Implications for hatchling sex ratios in the face of climate change. *Journal of Experimental Marine Biology and Ecology*, 474, 92-99, doi:10.1016/j.jembe.2015.09.015.
Lama, P., 2018: Gendered consequences of mobility for adaptation in small island developing states: case studies from Maafushi and Kudafari in the Maldives. *Island Studies Journal*, 13(2), 111-128, doi:10.24043/isj.64.
Lang'at, J. K. et al., 2014: Rapid losses of surface elevation following tree girdling and cutting in tropical mangroves. *PLoS One*, 9(9), e107868, doi:10.1371/journal.pone.0107868.
Lashley, J. and K. Warner, 2013: Evidence of demand for microinsurance for coping and adaptation to weather extremes in the Caribbean. *Climatic Change*, 133(1), 101-112, doi:10.1007/s10584-013-0922-1.
Lasso, A. and H. Dahles, 2018: Are tourism livelihoods sustainable? Tourism development and economic transformation on Komodo Island, Indonesia. *Asia Pacific Journal of Tourism Research*, 23(5), 473-485, doi:10.1080/10941665.2018.1467939.
Layne, D., 2017: Impacts of Climate Change on Tourism in the Coastal and Marine Enviornments of Caribbean Small Island Developing States (SIDS). In: *Caribbean Marine Climate Change Report Card: Science Review 2017.* [Buckley, P., B. Townhill, U. Trotz, K. Nichols, P. Murray, C. Clarke-Samuels, A. Gordon and M. Taylor (eds.)].
Lazenby, M. J., M. C. Todd, R. Chadwick and Y. Wang, 2018: Future Precipitation Projections over Central and Southern Africa and the Adjacent Indian Ocean: What Causes the Changes and the Uncertainty? *Journal of Climate*, 31(12), 4807-4826, doi:10.1175/jcli-d-17-0311.1.
Lazrus, H., 2015: Risk Perception and Climate Adaptation in Tuvalu: A Combined Cultural Theory and Traditional Knowledge Approach. *Human Organization*, 74(1), doi:10.17730/humo.74.1.q0667716284749m8.
Le Dé, L., T. Rey, F. Leone and D. Gilbert, 2018: Sustainable livelihoods and effectiveness of disaster responses: a case study of tropical cyclone Pam in Vanuatu. *Natural Hazards*, 91(3), 1203-1221, doi:10.1007/s11069-018-3174-6.
Lee, S., S. Wu and A. Li, 2018: Low-carbon tourism of small islands responding to climate change. *World Leisure Journal*, 60(3), 235-245, doi:10.1080/16078055.2018.1496530.
Lehner, F. et al., 2017: Projected drought risk in 1.5°C and 2°C warmer climates. *Geophysical Research Letters*, 44(14), 7419-7428, doi:10.1002/2017gl074117.
Lemahieu, A. et al., 2018: Local perceptions of environmental changes in fishing communities of southwest Madagascar. *Ocean & Coastal Management*, 163, 209-221, doi:10.1016/j.ocecoaman.2018.06.012.
Lichtveld, M., 2018: Disasters Through the Lens of Disparities: Elevate Community Resilience as an Essential Public Health Service. *American Journal of Public Health*, 108(1), 28-30, doi:10.2105/AJPH.2017.304193.
Lieber, M. et al., 2020: A systematic review and meta-analysis assessing the impact of droughts, flooding, and climate variability on malnutrition. *Global Public Health*, 1-15, doi:10.1080/17441692.2020.1860247.
Lix, J. K. et al., 2016: Differential bleaching of corals based on El Nino type and intensity in the Andaman Sea, southeast Bay of Bengal. *Environmental Monitoring and Assessment*, 188(3), 175, doi:10.1007/s10661-016-5176-8.
Loehr, J., 2019: The Vanuatu Tourism Adaptation System: a holistic approach to reducing climate risk. *Journal of Sustainable Tourism*, 28(4), 515-534, doi:10.1080/09669582.2019.1683185.
Loehr, J., S. Becken, J. Nalau and B. Mackey, 2020: Exploring the multiple benefits of ecosystem-based adaptation for climate risks and destination well-being. *Journal of Hospitality & Tourism Research*, doi:0.1177/1096348020944438.
Look, C., E. Friedman and G. Godbout, 2019: The Resilience of Land Tenure Regimes During Hurricane Irma: How Colonial Legacies Impact Disaster Response and Recovery in Antigua and Barbuda. *Journal of Extreme Events*, 06(01), doi:10.1142/s2345737619400049.

Lopez-Candales, A., D. F. Hernandez-Suarez, A. D. Osterman-Pla and J. G. Conde-Santiago, 2018: A Reminder From the Devastation Hurricane Maria Left Behind. *Cureus*, 10(1), e2038, doi:10.7759/cureus.2038.
Lopez-Marrero, T., 2010: An integrative approach to study and promote natural hazards adaptive capacity: a case study of two flood-prone communities in Puerto Rico. *Geographical Journal*, 176(2), 150-163, doi:10.1111/j.1475-4959.2010.00353.x.
Lough, J. M. et al., 2016: Observed and projected changes in surface climate of tropical Pacific Islands. In: *Vulnerability of Pacific Island agriculture and forestry to climate change* [Taylor, M., A. McGregor and B. Dawson (eds.)]. Pacific Community, pp. 47-101.
Lovelock, C. E. et al., 2015: The vulnerability of Indo-Pacific mangrove forests to sea-level rise. *Nature*, 526(7574), 559-563, doi:10.1038/nature15538.
Lowe, R. et al., 2018: Nonlinear and delayed impacts of climate on dengue risk in Barbados: A modelling study. *PLoS Medicine*, 15(7), e1002613, doi:10.1371/journal.pmed.1002613.
Lubell, M. and M. Niles, 2019: The limits of capacity building. *Nature Climate Change*, 9(8), 578-579, doi:10.1038/s41558-019-0541-6.
Luetz, J., 2017: Chapter 3: Climate change and migration in the Maldives: Some lessons for policy makers. In: *Climate Change Adaptation in Pacific Countries: Fostering resilience and improving the quality of life* [Filho, W. L. (ed.)]. Springer, Cham. ISBN 978-3-319-50093-5.
Luke, S. H. et al., 2017: The effects of catchment and riparian forest quality on stream environmental conditions across a tropical rainforest and oil palm landscape in Malaysian Borneo. *Ecohydrology*, 10(4), e1827, doi:10.1002/eco.1827.
Lumbroso, D., E. Brown and N. Ranger, 2016: Stakeholders' perceptions of the overall effectiveness of early warning systems and risk assessments for weather-related hazards in Africa, the Caribbean and South Asia. *Natural Hazards*, 84(3), 2121-2144, doi:10.1007/s11069-016-2537-0.
Mace, M. J. and R. Verheyen, 2016: Loss, Damage and Responsibility after COP21: All Options Open for the Paris Agreement. *Review of European, Comparative & International Environmental Law*, 25(2), 197-214, doi:10.1111/reel.12172.
Mackay, E. and A. Spencer, 2017: The future of Caribbean tourism: competition and climate change implications. *Worldwide Hospitality and Tourism Themes*, 9(1), 44-59, doi:10.1108/whatt-11-2016-0069.
MacKenzie, R. A. et al., 2016: Sedimentation and belowground carbon accumulation rates in mangrove forests that differ in diversity and land use: a tale of two mangroves. *Wetlands Ecology and Management*, 24(2), 245-261, doi:10.1007/s11273-016-9481-3.
Magee, A. D., D. C. Verdon-Kidd, A. S. Kiem and S. A. Royle, 2016: Tropical cyclone perceptions, impacts and adaptation in the Southwest Pacific: an urban perspective from Fiji, Vanuatu and Tonga. *Natural Hazards and Earth System Sciences*, 16(5), 1091-1105, doi:10.5194/nhess-16-1091-2016.
Magel, J., S. Dimoff and J. K. Baum, 2020: Direct and indirect effects of climate change-amplified pulse heat stress events on coral reef fish communities. *Ecological Applications*, 30(6), doi:10.1002/eap.2124.
Magnan, A., 2006: L'evacuation des populations aux Maldives apres le tsunami du 26 decembre 2004. *Mappemonde*, 84(4).
Magnan, A. and V. Duvat, 2018: Unavoidable solutions for coastal adaptation in Reunion Island (Indian Ocean). *Environmental Science & Policy*, 89, 393-400, doi:10.1016/j.envsci.2018.09.002.
Magnan, A. K. et al., 2019: Cross Chapter Box 9: Low Lying Islands and Coasts. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H. O., D. Roberts, V. Masson-Delmotte, P. Zhai, Y. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)].
Magnan, Alexandre K. et al., 2018: Atoll population exposure to marine inundation: the example of the Tuamotu Archipelago (Rangiroa and Tikehau atolls), French Polynesia. *VertigO*, 18(3), doi:10.4000/vertigo.23607.
Mahadew, R. and K. Appadoo, 2019: Tourism and climate change in Mauritius: assessing the adpatation and mitigation plans and prospects. *Tourism Review*, doi:10.1108/TR-12-2017-0203.
Maharaj, S. et al., 2019: Assessing protected area effectiveness within the Caribbean under changing climate conditions: A case study of the small island, Trinidad. *Land Use Policy*, 81, 185-193, doi:10.1016/j.landusepol.2018.09.030.
Maharaj, S. and M. New, 2013: Modelling individual and collective species responses to climate change within Small Island States. *Biological Conservation*, 167, 283-291, doi:10.1016/j.biocon.2013.08.027.
Mahon, R. et al., 2019: Fit for purpose? Transforming National Meteorological and Hydrological T Services into National Climate Service Centers. *Climate Services*, 13, 14-23, doi:10.1016/j.cliser.2019.01.002.
Major, D. C. and S. Juhola, 2016: Guidance for Climate Change Adaptation in Small Coastal Towns and Cities: A New Challenge. *Journal of Urban Planning and Development*, 142(4), doi:10.1061/(asce)up.1943-5444.0000356.
Mallin, M., 2018: From sea-level rise to seabed grabbing: The political economy of climate change in Kiribati. *Marine Policy*, 97, 244-252, doi:10.1016/j.marpol.2018.04.021.
Malsale, P. et al., 2018: Protocols and Partnerships for Engaging Pacific Island Communities in the Collection and Use of Traditional Climate Knowledge. *Bulletin of the American Meteorological Society*, 99(12), 2471-2489, doi:10.1175/bams-d-17-0163.1.
Manes, S. et al., 2021: Endemism increases species' climate change risk in areas of global biodiversity importance. *Biological Conservation*, 257, doi:10.1016/j.biocon.2021.109070.

Mann, T. and H. Westphal, 2014: Assessing Long-Term Changes in the Beach Width of Reef Islands Based on Temporally Fragmented Remote Sensing Data. *Remote Sensing*, 6(8), 6961-6987, doi:10.3390/rs6086961.
Marino, E. and H. Lazrus, 2015: Migration or Forced Displacement?: The Complex Choices of Climate Change and Disaster Migrants in Shishmaref, Alaska and Nanumea, Tuvalu. *Human Organization*, 74(4), 341-350, doi:10.17730/0018-7259-74.4.341.
Mariotti, A., Y. Pan, N. Zeng and A. Alessandri, 2015: Long-term climate change in the Mediterranean region in the midst of decadal variability. *Climate Dynamics*, 44(5-6), 1437-1456, doi:10.1007/s00382-015-2487-3.
Marler, T., 2014: Pacific island tropical cyclones are more frequent and globally relevant, yet less studied. *Frontiers in Environmental Science*, 2, doi:10.3389/fenvs.2014.00042.
Martin, D. et al., 2015: Development and implementation of a climate data management system for western Pacific small island developing states. *Meteorological Applications*, 22(2), 273-287, doi:10.1002/met.1461.
Martin, P., P. Nunn, J. Leon and N. Tindale, 2018: Responding to multiple climate-linked stressors in a remote island context: The example of Yadua Island, Fiji. *Climate Risk Management*, 21, 7-15, doi:10.1016/j.crm.2018.04.003.
Martins, P. et al., 2009: Under-report and underdiagnosis of chronic respiratory diseases in an African country. *Allergy*, 64(7), 1061-1067, doi:10.1111/j.1398-9995.2009.01956.x.
Martyr-Koller, R. et al., 2021: Loss and damage implications of sea-level rise on Small Island Developing States. *Current Opinion in Environmental Sustainability*, 50, 245-259, doi:10.1016/j.cosust.2021.05.001.
Marzeion, B. and A. Levermann, 2014: Loss of cultural world heritage and currently inhabited places to sea-level rise. *Environmental Research Letters*, 9(3), doi:10.1088/1748-9326/9/3/034001.
Masterson, J. et al., 2014: Effects of sea-level rise on barrier island groundwater system dynamics - ecohydrological implications. *Ecohydrology*, 7(3), 1064-1071, doi:10.1002/eco.1442.
Maynard, J. et al., 2015: Projections of climate conditions that increase coral disease susceptibility and pathogen abundance and virulence. *Nature Climate Change*, 5(7), 688-694, doi:10.1038/nclimate2625.
McAneney, J., R. van den Honert and S. Yeo, 2017: Stationarity of major flood frequencies and heights on the Ba River, Fiji, over a 122-year record. *International Journal of Climatology*, 37, 171-178, doi:10.1002/joc.4989.
McClanahan, T. R. et al., 2019: Temperature patterns and mechanisms influencing coral bleaching during the 2016 El Niño. *Nature Climate Change*, 9(11), 845-851, doi:10.1038/s41558-019-0576-8.
McClanahan, T. R. et al., 2020: Large geographic variability in the resistance of corals to thermal stress. *Global Ecology and Biogeography*, 29(12), 2229-2247, doi:10.1111/geb.13191.
McCubbin, S., T. Pearce, J. Ford and B. Smit, 2017: Social-ecological change and implications for food security in Funafuti, Tuvalu. *Ecology and Society*, 22(1), doi:10.5751/es-09129-220153.
McCubbin, S., B. Smit and T. Pearce, 2015: Where does climate fit? Vulnerability to climate change in the context of multiple stressors in Funafuti, Tuvalu. *Global Environmental Change*, 30, 43-55, doi:10.1016/j.gloenvcha.2014.10.007.
McField, M., 2017: Impacts of Climate Change on Coral in the Coastal and Marine Environments of Caribbean Small Island Developing States (SIDS). *Caribbean Marine Climate Change Report Card: Science Review 2017.*, 52-59.
McGaw, I. J., T. E. Van Leeuwen, R. H. Trehern and A. E. Bates, 2019: Changes in precipitation may alter food preference in an ecosystem engineer, the black land crab, Gecarcinus ruricola. *PeerJ*, 7, e6818, doi:10.7717/peerj.6818.
McGinn, A. and A. Solofa, 2020: Chapter 12: Mutli-level governance of climate change adaptation: A case study of country-wide adaptation projects in Samoa. In: *Managing Climate Change Adaptation in the Pacific Region* [Filho, W. L. (ed.)]. Springer International, pp. 231-253.
McGree, S. et al., 2019: Recent Changes in Mean and Extreme Temperature and Precipitation in the Western Pacific Islands. *Journal of Climate*, 32(16), 4919-4941, doi:10.1175/jcli-d-18-0748.1.
McGree, S., S. Schreider and Y. Kuleshov, 2016: Trends and Variability in Droughts in the Pacific Islands and Northeast Australia. *Journal of Climate*, 29(23), 8377-8397, doi:10.1175/jcli-d-16-0332.1.
McGree, S., S. Schreider, Y. Kuleshov and B. Prakash, 2020: On the use of mean and extreme climate indices to predict sugar yield in western Fiji. *Weather and Climate Extremes*, 29, doi:10.1016/j.wace.2020.100271.
McInnes, K. et al., 2016: Application of a synthetic cyclone method for assessment of tropical cyclone storm tides in Samoa. *Natural Hazards*, 80(1), 425-444, doi:10.1007/s11069-015-1975-4.
McInnes, K. et al., 2014: Quantifying storm tide risk in Fiji due to climate variability and change. *Global and Planetary Change*, 116, 115-129, doi:10.1016/j.gloplacha.2014.02.004.
McIver, L. 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, doi:10.1289/ehp.1509756.
McIver, L. et al., 2014: Assessment of the health impacts of climate change in Kiribati. *International Journal of Environmental Research and Public Health*, 11(5), 5224-5240, doi:10.3390/ijerph110505224.
McLean, R. and P. Kench, 2015: Destruction or persistence of coral atoll islands in the face of 20th and 21st century sea-level rise? *Wiley Interdisciplinary Reviews: Climate Change*, 6(5), 445-463, doi:10.1002/wcc.350.
McLeod, E. et al., 2018: Raising the voices of Pacific Island women to inform climate adaptation policies. *Marine Policy*, 93, 178-185, doi:10.1016/j.marpol.2018.03.011.
McLeod, E. et al., 2019: Lessons From the Pacific Islands – Adapting to Climate Change by Supporting Social and Ecological Resilience. *Frontiers in Marine Science*, 6, doi:10.3389/fmars.2019.00289.

McMichael, A., M. Katonivualiku and T. Powell, 2019: Planned relocation and everyday agency in low-lying coastal villages in Fiji. *Geography Journal*, 185, 325-337, doi:10.1111/geoj.12312.
McMillen, H. L. et al., 2014: Small islands, valuable insights: systems of customary resource use and resilience to climate change in the Pacific. *Ecology and Society*, 19(4), doi:10.5751/es-06937-190444.
McNamara, K., R. Bronen, N. Fernando and S. Klepp, 2016: The complex decision-making of climate-induced relocation: adaptation and loss and damage. *Climate Policy*, doi:10.1080/14693062.2016.1248886.
McNamara, K. and H. Des Combes, 2015: Planning for Community Relocations Due to Climate Change in Fiji. *International Journal of Disaster Risk Science*, 6(3), 315-319, doi:10.1007/s13753-015-0065-2.
McNamara, K. E. et al., 2019: What is shaping vulnerability to climate change? The case of Laamu Atoll, Maldives. *Island Studies Journal*, 14(1), 81-100, doi:10.24043/isj.67.
McNamara, K. E. et al., 2020: An assessment of community-based adaptation initiatives in the Pacific Islands. *Nature Climate Change*, 10(7), 628-639, doi:10.1038/s41558-020-0813-1.
McNaught, R., O. Warrick and A. Cooper, 2014: Communicating climate change for adaptation in rural communities: a Pacific study. *Regional Environmental Change*, 14(4), 1491-1503, doi:10.1007/s10113-014-0592-1.
McSherry, A., E. J. Manalastas, J. C. Gaillard and S. N. M. Dalisay, 2014: From Deviant to Bakla, Strong to Stronger: Mainstreaming Sexual and Gender Minorities into Disaster Risk Reduction in the Philippines. *Forum for Development Studies*, 42(1), 27-40, doi:10.1080/08039410.2014.952330.
Mecartney, S. and J. Connell, 2017: Urban Melanesia: The Challenges of Managing Land, Modernity and Tradition. In: *Kastom, property and ideology* [McDonnell, S., M. Allen and C. Filer (eds.)]. Australian National University Press, pp. 57-84. ISBN 9781760461058.
MedECC, 2020: Summary for Policymakers. In: *Climate and Environmental Change in the Mediterranean basin—Current Situation and Risks for the Future. First Mediterranean Assessment Report* [Cramer, W., J. Guiot and K. Marini (eds.)]. Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France, pp. 34.
Melendez, E. and J. Hinojosa, 2017: *Estimates of Post-Hurricane Maria Exodus from Puerto Rico*. Center for Puerto Rican Studies, Hunter College.
Mendez-Lazaro, P. et al., 2018: A heat vulnerability index to improve urban public health management in San Juan, Puerto Rico. *International Journal of Biometeorology*, 62(5), 709-722, doi:10.1007/s00484-017-1319-z.
Mentaschi, L. et al., 2017: Global changes of extreme coastal wave energy fluxes triggered by intensified teleconnection patterns. *Geophysical Research Letters*, 44, 2416-2426, doi:10.1002/2016GL072488.
Mentaschi, L. et al., 2018: Global long-term observations of coastal erosion and accretion. *Scientific Reports*, 8(1), 12876, doi:10.1038/s41598-018-30904-w.
Mercer, J., I. Kelman, B. Alfthan and T. Kurvits, 2012: Ecosystem-Based Adaptation to Climate Change in Caribbean Small Island Developing States: Integrating Local and External Knowledge. *Sustainability*, 4(8), 1908-1932, doi:10.3390/su4081908.
Mercer, J. et al., 2014a: Nation-building policies in Timor-Leste: disaster risk reduction, including climate change adaptation. *Disasters*, 38(4), 690-718, doi:10.1111/disa.12082.
Mercer, J., T. Kurvits, I. Kelman and S. Mavrogenis, 2014b: Ecosystem-Based Adaptation for Food Security in the AIMS SIDS: Integrating External and Local Knowledge. *Sustainability*, 6(9), 5566-5597, doi:10.3390/su6095566.
Merrifield, M. and M. Maltrud, 2011: Regional sea level trends due to a Pacific trade wind intensification. *Geophysical Research Letters*, 38(21), n/a-n/a, doi:10.1029/2011gl049576.
Mertz, O. et al., 2010: Sustainable land use in Tikopia: Food production and consumption in an isolated agricultural system. *Singapore Journal of Tropical Geography*, 31(1), 10-26, doi:10.1111/j.1467-9493.2010.00389.x.
Middelbeek, L., K. Kolle and H. Verrest, 2014: Built to last? Local climate change adaptation and governance in the Caribbean – The case of an informal urban settlement in Trinidad and Tobago. *Urban Climate*, 8, 138-154, doi:10.1016/j.uclim.2013.12.003.
Middleton, N. et al., 2008: A 10-year time-series analysis of respiratory and cardiovascular morbidity in Nicosia, Cyprus: the effect of short-term changes in air pollution and dust storms. *Environmental Health*, 7, 39, doi:10.1186/1476-069X-7-39.
Mitsch, W. and M. Hernandez, 2013: Landscape and climate change threats to wetlands of North and Central America. *Aquatic Sciences*, 75(1), 133-149, doi:10.1007/s00027-012-0262-7.
Mollica, N. R. et al., 2019: Skeletal records of bleaching reveal different thermal thresholds of Pacific coral reef assemblages. *Coral Reefs*, 38(4), 743-757, doi:10.1007/s00338-019-01803-x.
Moncada, S. and H. Bambrick, 2019: Extreme weather events in Small Island Developing States: barriers to climate change adaptation among coastal communities in a remote island of Fiji. In: *Dealing with climate change on small islands: Towards effective and sustainable adaptation* [Klock, C. and M. Fink (eds.)]. Gottingen University Press, Germany, pp. 217-247. ISBN 978-3-86395-435-2.
Mondragón, C., 2018: Forest, Reef and Sea-Level Rise in North Vanuatu: Seasonal Environmental Practices and Climate Fluctuations in Island Melanesia. In: *Indigenous Knowledge for Climate Change Assessment and Adaptation* [Nakashima, D., I. Krupnik and J. Rubis (eds.)]. Cambridge University Press, Cambridge, pp. 23-40. ISBN 9781316481066.
Monioudi, I. N. et al., 2017: Assessment of island beach erosion due to sea level rise: the case of the Aegean archipelago (Eastern Mediterranean). *Natural Hazards and Earth System Sciences*, 17(3), 449-466, doi:10.5194/nhess-17-449-2017.

Monioudi, I. N. et al., 2018: Climate change impacts on critical international transportation assets of Caribbean Small Island Developing States (SIDS): the case of Jamaica and Saint Lucia. *Regional Environmental Change*, 18(8), 2211-2225, doi:10.1007/s10113-018-1360-4.

Monnereau, I. et al., 2017: The impact of methodological choices on the outcome of national-level climate change vulnerability assessments: An example from the global fisheries sector. *Fish and Fisheries*, 18(4), 717-731, doi:10.1111/faf.12199.

Monoy, C. et al., 2016: Temporal Changes in Tree Species and Trait Composition in a Cyclone-prone Pacific Dipterocarp Forest. *Ecosystems*, 19(6), 1013-1022, doi:10.1007/s10021-016-9983-0.

Morim, J. et al., 2019: Robustness and uncertainties in global multivariate wind-wave climate projections. *Nature Climate Change*, 9(9), 711-718, doi:10.1038/s41558-019-0542-5.

Morri, C. et al., 2015: Through bleaching and tsunami: Coral reef recovery in the Maldives. *Marine Pollution Bulletin*, 98(1-2), 188-200, doi:10.1016/j.marpolbul.2015.06.050.

Morris, R., T. Konlechner, M. Ghisalberti and S. Swearer, 2018: From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. *Global Change Biology*, 24(5), 1827-1842, doi:10.1111/gcb.14063.

Moulton, A. A. and M. R. Machado, 2019: Bouncing Forward After Irma and Maria: Acknowledging Colonialism, Problematizing Resilience and Thinking Climate Justice. *Journal of Extreme Events*, 06(01), doi:10.1142/s2345737619400037.

Mycoo, M., 2014a: Autonomous household responses and urban governance capacity building for climate change adaptation: Georgetown, Guyana. *Urban Climate*, 9, 134-154, doi:10.1016/j.uclim.2014.07.009.

Mycoo, M., 2014b: Sustainable tourism, climate change and sea level rise adaptation policies in Barbados. *Natural Resources Forum*, 38(1), 47-57, doi:10.1111/1477-8947.12033.

Mycoo, M., 2015: Communicating climate change in rural coastal communities. *International Journal of Climate Change Strategies and Management*, 7(1), 58-75, doi:10.1108/ijccsm-04-2013-0042.

Mycoo, M., 2017: A Caribbean New Urban Agenda post-Habitat III: Closing the gaps. *Habitat International*, 69, 68-77, doi:10.1016/j.habitatint.2017.09.001.

Mycoo, M., 2018a: Beyond 1.5 °C: vulnerabilities and adaptation strategies for Caribbean Small Island Developing States. *Regional Environmental Change*, 18(8), 2341-2353, doi:10.1007/s10113-017-1248-8.

Mycoo, M., 2018b: Urban sustainability in Caribbean Small Island Developing States: a conceptual framework for urban planning using a case study of Trinidad. *International Development Planning Review*, 40(2), 143-174, doi:10.3828/idpr.2018.8.

Mycoo, M., 2020: Environmental governance in small island developing states: Challenges and opportunities for transformation using a Trinidad and Tobago case study. In: *Handbook of Governance in Small States.* [Briguglio, L., J. Byron, S. Moncada and W. Veenendaal (eds.)]. Routledge, London, UK. ISBN 9780429061356.

Mycoo, M., 2021: Vulnerabilities to Climate Change and Enhancing Resilience in Caribbean Small Island Developing States: A Spatial Planning Framework. In: *Small Island Developing States: vulnerability and resilience under climate change* [Moncada, S., L. Briguglio, H. Bambrick, I. Kelman, C. Iorns and L. Nurse (eds.)]. Springer, Cham, Switzerland.

Mycoo, M. and M. Donovan, 2017: *A Blue Urban Agenda: Adapting to Cliamte Change in the Coastal Cities of Caribbean and Pacific Small Island Developing States*. IBD, Washington, D.C. ISBN 978-1-59782-293-1.

Nalau, J., S. Becken and B. Mackey, 2018a: Ecosystem-based Adaptation: A review of the constraints. *Environmental Science & Policy*, 89, 357-364, doi:10.1016/j.envsci.2018.08.014.

Nalau, J. et al., 2018b: The Role of Indigenous and Traditional Knowledge in Ecosystem-Based Adaptation: A Review of the Literature and Case Studies from the Pacific Islands. *Weather, Climate, and Society*, 10(4), 851-865, doi:10.1175/wcas-d-18-0032.1.

Nalau, J. and W. L. Filho, 2018: Introduction: Limits to Adaptation. In: *Limits to Climate Change Adaptation* [Filho, W. and J. Nalau (eds.)]. Springer, Cham.

Nalau, J., J. Handmer and M. Dalesa, 2017: The role and capacity of government in climate crises: TC Pam in Vanuatu. In: *Climate Change Adaptation in Pacific Countries: Fostering Resilience and Improving the Quality of Life* [Filho, W. L. (ed.)]. Springer, Berlin, pp. 151-161.

Nalau, J. et al., 2016: The practice of integrating adaptation and disaster risk reduction in the south-west Pacific. *Climate and Development*, 8(4), 365-375, doi:10.1080/17565529.2015.1064809.

Nand, M. M. and D. K. Bardsley, 2020: Climate change loss and damage policy implications for Pacific Island Countries. *Local Environment*, 25(9), 725-740, doi:10.1080/13549839.2020.1825357.

Narayan, S. et al., 2016: The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences. *PLoS One*, 11(5), e0154735, doi:10.1371/journal.pone.0154735.

Narayan, S. et al., 2020: Local adaptation responses to coastal hazards in small island communities: insights from 4 Pacific nations. *Environmental Science & Policy*, 104, 199-207, doi:10.1016/j.envsci.2019.11.006.

Naylor, A., 2015: Island morphology, reef resources, and development paths in the Maldives. *Progress in Physical Geography*, 39(6), 728-749, doi:10.1177/0309133315598269.

Neef, A. et al., 2018: Climate adaptation strategies in Fiji: The role of social norms and cultural values. *World Development*, 107, 125-137, doi:10.1016/j.worlddev.2018.02.029.

Nehru, P. and P. Balasubramanian, 2018: Mangrove species diversity and composition in the successional habitats of Nicobar Islands, India: A post-tsunami and subsidence scenario. *Forest Ecology and Management*, 427, 70-77, doi:10.1016/j.foreco.2018.05.063.
Newth, D. and D. Gunasekera, 2018: Projected Changes in Wet-Bulb Globe Temperature under Alternative Climate Scenarios. *Atmosphere*, 9(5), doi:10.3390/atmos9050187.
Nguyen, P. et al., 2018: Global Precipitation Trends across Spatial Scales Using Satellite Observations. *Bulletin of the American Meteorological Society*, 99(4), 689-697, doi:10.1175/bams-d-17-0065.1.
Nicolas, F. et al., 2020: Assessing the Potential Impact of Climate Change on Rice Yield in the Artibonite Valley of Haiti Using the CSM-CERES-Rice Model. *Transactions of the ASABE*, 63(5), 1385-1400, doi:10.13031/trans.13868.
Noy, I. and C. Edmonds, 2019: Increasing fiscal resilience to disasters in the Pacific. *Natural Hazards*, 97(3), 1375-1393, doi:10.1007/s11069-019-03719-9.
Nunn, P., 2013: The end of the Pacific? Effects of sea level rise on Pacific Island livelihoods. *Singapore Journal of Tropical Geography*, 34(2), 143-171, doi:10.1111/sjtg.12021.
Nunn, P., W. Aalbersberg, S. Lata and M. Gwilliam, 2014: Beyond the core: community governance for climate-change adaptation in peripheral parts of Pacific Island Countries. *Regional Environmental Change*, 14(1), 221-235, doi:10.1007/s10113-013-0486-7.
Nunn, P., A. Kohler and R. Kumar, 2017a: Identifying and assessing evidence for recent shoreline change attributable to uncommonly rapid sea-level rise in Pohnpei, Federated States of Micronesia, Northwest Pacific Ocean. *Journal of Coastal Conservation*, 21(6), 719-730, doi:10.1007/s11852-017-0531-7.
Nunn, P. and R. Kumar, 2018: Understanding climate-human interactions in Small Island Developing States (SIDS). *International Journal of Climate Change Strategies and Management*, 10(2), 245-271, doi:10.1108/ijccsm-01-2017-0012.
Nunn, P. and R. Kumar, 2019a: Measuring Peripherality as a Proxy for Autonomous Community Coping Capacity: A Case Study from Bua Province, Fiji Islands, for Improving Climate Change Adaptation. *Social Sciences*, 8(8), doi:10.3390/socsci8080225.
Nunn, P., J. Runman, M. Falanruw and R. Kumar, 2017b: Culturally grounded responses to coastal change on islands in the Federated States of Micronesia, northwest Pacific Ocean. *Regional Environmental Change*, 17(4), 959-971, doi:10.1007/s10113-016-0950-2.
Nunn, P. D., C. Klöck and V. Duvat, 2021: Seawalls as maladaptations along island coasts. *Ocean & Coastal Management*, 205, doi:10.1016/j.ocecoaman.2021.105554.
Nunn, P. D., L. Kumar, I. Eliot and R. F. McLean, 2016: Classifying Pacific islands. *Geoscience Letters*, 3(1), doi:10.1186/s40562-016-0041-8.
Nunn, P. D. and R. Kumar, 2019b: Cashless Adaptation to Climate Change: Unwelcome yet Unavoidable? *One Earth*, 1(1), 31-34, doi:10.1016/j.oneear.2019.08.004.
Nunn, P. D. and K. E. McNamara, 2019: Failing adaptation in island contexts: the growing need for transformational change. In: *Dealing with climate change on small islands: Towards effective and sustainable adaptation*, pp. 19-44. ISBN 978-3-86395-435-2.
Nurse, L., 2011: The implications of global climate change for fisheries management in the Caribbean. *Climate and Development*, 3(3), 228-241, doi:10.1080/17565529.2011.603195.
Oakes, R., 2019: Culture, climate change and mobility decisions in Pacific Small Island Developing States. *Population and Environment*, 40(4), 480-503, doi:10.1007/s11111-019-00321-w.
Oberle, F., P. Swarzenski and C. Storlazzi, 2017: Atoll Groundwater Movement and Its Response to Climatic and Sea-Level Fluctuations. *Water*, 9(650), doi:10.3390/w9090650.
Oculi, N. and S. Stephenson, 2018: Conceptualizing climate vulnerability: Understanding the negotiating strategies of Small Island Developing States. *Environmental Science & Policy*, 85, 72-80, doi:10.1016/j.envsci.2018.03.025.
Oleson, K. L. L. et al., 2018: Charting progress towards system-scale ecosystem service valuation in islands. *Environmental Conservation*, 45(03), 212-226, doi:10.1017/s0376892918000140.
Onaka, S. et al., 2017: Effectiveness of Gravel Beach Nourishment on Pacific Island. *Asian and Pacific Coastas*, 651-662, doi:10.1142/9789813233812_0059.
Ontoria, Y. et al., 2019: Interactive effects of global warming and eutrophication on a fast-growing Mediterranean seagrass. *Marine Environmental Research*, 145, 27-38, doi:10.1016/j.marenvres.2019.02.002.
Oppenheimer, M. et al., 2019: Chapter 4: Seal level rise and implications for low lying islands, coasts and communities. In: *IPCC Special Report on Ocean and Cryosphere* [Portner, H. O., D. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegria, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)].
Oremus, K. L. et al., 2020: Governance challenges for tropical nations losing fish species due to climate change. *Nature Sustainability*, 3(4), 277-280, doi:10.1038/s41893-020-0476-y.
Oritz, P. et al., 2015: Spatial Models for Prediction and Early Warning of Aedes aegypti Proliferation from Data on Climate Change and Variability in Cuba. *MEDICC Review*, 17(2), 20-28.
Otto, I. et al., 2017: Social vulnerability to climate change: a review of concepts and evidence. *Regional Environmental Change*, 17(6), 1651-1662, doi:10.1007/s10113-017-1105-9.

Oviatt, C. A., K. Huizenga, C. S. Rogers and W. J. Miller, 2019: What nutrient sources support anomalous growth and the recent sargassum mass stranding on Caribbean beaches? A review. *Marine Pollution Bulletin*, 145, 517-525, doi:10.1016/j.marpolbul.2019.06.049.
Paeniu, L., E. Holland, C. Miller and G. Anderson, 2017: Rainfall Trends, Drought Frequency and La Niña in Tuvalu: A Small Equatorial Island State in the Pacific Ocean. *Journal of Environmental & Analytical Toxicology*, 07(05), doi:10.4172/2161-0525.1000501.
Paeth, H. et al., 2017: Quantifying the evidence of climate change in the light of uncertainty exemplified by the Mediterranean hot spot region. *Global and Planetary Change*, 151, 144-151, doi:10.1016/j.gloplacha.2016.03.003.
Palanisamy, H. et al., 2012: Regional sea level change and variability in the Caribbean sea since 1950. *Journal of Geodetic Science*, 2(2), 125-133, doi:10.2478/v10156-011-0029-4.
Papadimitriou, L. et al., 2019: Developing a water strategy for sustainable irrigated agriculture in Mediterranean island communities – Insights from Malta. *Outlook on Agriculture*, 48(2), 143-151, doi:10.1177/0030727019841060.
Parsons, M., C. Brown, J. Nalau and K. Fisher, 2018: Assessing adaptive capacity and adaptation: insights from Samoan tourism operators. *Climate and Development*, 10(7), 644-663, doi:10.1080/17565529.2017.1410082.
Parsons, M. and J. Nalau, 2019: Adaptation policy and planning in Pacific small island developing states. In: *Research Handbook on Climate Change Adaptation Policy* [Keskitalo, C. and B. Preston (eds.)]. Edward Elgar Publishing, Cheltenham, UK, pp. 273-290.
Parsons, M., J. Nalau and K. Fisher, 2017: Alternative Perspectives on Sustainability: Indigenous Knowledge and Methodologies. *Challenges in Sustainability*, 5(1), doi:10.12924/cis2017.05010007.
Pascua, P. a. et al., 2017: Beyond services: A process and framework to incorporate cultural, genealogical, place-based, and indigenous relationships in ecosystem service assessments. *Ecosystem Services*, 26, 465-475, doi:10.1016/j.ecoser.2017.03.012.
Pawankar, R. et al., 2020: Asia Pacific Association of Allergy Asthma and Clinical Immunology White Paper 2020 on climate change, air pollution, and biodiversity in Asia-Pacific and impact on allergic diseases. *Asia Pacific Allergy*, 10(1), e11, doi:10.5415/apallergy.2020.10.e11.
PCRAFI, 2017: *PCRAFI Program Phase II: Furthering Disaster Risk Finance in the Pacific*. SPC, Pacific Islands Forum Secretariat, World Bank Group. Available at: https://www.financialprotectionforum.org/publication/pcrafi-program-phase-ii-furthering-disaster-risk-finance-in-the-pacific.
Pecl, G. T. et al., 2017: Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*, 355(6332), doi:10.1126/science.aai9214.
Pedersen, O. et al., 2016: Heat stress of two tropical seagrass species during low tides - impact on underwater net photosynthesis, dark respiration and diel in situ internal aeration. *New Phytologist*, 210(4), 1207-1218, doi:10.1111/nph.13900.
Perdikaris, S. et al., 2017: Cultural heritage under threat: the effects of climate change on the small island of Barbuda, Lesser Antilles. In: *Public Archaeology and Climate Change* [Dawson, T., C. Nimura, E. Lopez-Romero and M. Daire (eds.)]. Oxbow Books, Oxford, pp. 138-148. ISBN 9781785707070.
Perkins, R. and S. Krause, 2018: Adapting to climate change impacts in Yap State, Federated States of Micronesia: the importance of environmental conditions and intangible cultural heritage. *Island Studies Journal*, 13(1), 65-78, doi:10.24043/isj.51.
Perry, C. and K. Morgan, 2017: Bleaching drives collapse in reef carbonate budgets and reef growth potential on southern Maldives reefs. *Scientific Reports*, 7, 40581, doi:10.1038/srep40581.
Perry, C., K. Morgan, I. Lange and R. Yarlett, 2020: Bleaching-driven reef community shifts drive pulses of increased reef sediment generation. *Royal Society Open Science*, 7(192153), doi:10.1098/rsos.19215310.6084/m9.figshare.c.
Peters, E., 2015: The 2009/2010 Caribbean drought: a case study. *Disasters*, 39(4), 738-761, doi:10.1111/disa.12123.
Petzold, J. and A. Magnan, 2019: Climate change: thinking small islands beyond Small Island Developing States (SIDS). *Climatic Change*, 152(1), 145-165, doi:10.1007/s10584-018-2363-3.
Petzold, J. and B. Ratter, 2015: Climate change adaptation under a social capital approach – An analytical framework for small islands. *Ocean & Coastal Management*, 112, 36-43, doi:10.1016/j.ocecoaman.2015.05.003.
Petzold, J., B. Ratter and A. Holdschlag, 2018: Competing knowledge systems and adaptability to sea-level rise in The Bahamas. *Area*, 50(1), 91-100, doi:10.1111/area.12355.
Piggott-McKellar, A., K. McNamara, P. Nunn and S. Sekinini, 2019a: Moving People in a Changing Climate: Lessons from Two Case Studies in Fiji. *Social Sciences*, 8(133), doi:10.3390/socsci8050133.
Piggott-McKellar, A., K. McNamara, P. Nunn and J. Watson, 2019b: What are the barriers to successful community-based climate change adaptation? A review of grey literature. *Local Environment*, 24(4), 374-390, doi:10.1080/13549839.2019.1580688.
Piggott-McKellar, A., P. Nunn, K. McNamara and S. Sekinini, 2020: Dam(n) Seawalls: A case of climate change maladaptation in Fiji. In: *Managing Climate Change Adaptation in the Pacific Region* [Filho, W. L. (ed.)]. Springer International, pp. 69-84.
Pike, D. A., E. A. Roznik and I. Bell, 2015: Nest inundation from sea-level rise threatens sea turtle population viability. *Royal Society Open Science*, 2(7), 150127, doi:10.1098/rsos.150127.
Pillet, V. et al., 2019: Assessing the impacts of shoreline hardening on beach response to hurricanes: Saint-Barthelemy, Lesser Antilles. *Ocean and Coastal Management*, 174, 71-91, doi:10.1016/j.ocecoaman.2019.03.021.

Pinnegar, J. et al., 2019: Assessing vulnerability and adaptive capacity of the fisheries sector in Dominica: long-term climate change and catastrophic hurricanes. *ICES Joural of Marine Science*, 76(5), 1353-1367, doi:10.1093/icesjms/fsz052.
Pisapia, C. et al., 2016: Coral recovery in the central Maldives archipelago since the last major mass-bleaching, in 1998. *Scientific Reports*, 6, 34720, doi:10.1038/srep34720.
Pisapia, C., A. El Kateb, P. Hallock and S. Spezzaferri, 2017: Assessing coral reef health in the North Ari Atoll (Maldives) using the FoRAM Index. *Marine Micropaleontology*, 133, 50-57, doi:10.1016/j.marmicro.2017.06.001.
Plotz, R., L. Chambers and C. Finn, 2017: The Best of Both Worlds: A Decision-Making Framework for Combining Traditional and Contemporary Forecast Systems. *Journal of Applied Meteorology and Climatology*, 56(8), 2377-2392, doi:10.1175/jamc-d-17-0012.1.
Popke, J., S. Curtis and D. Gamble, 2016: A social justice framing of climate change discourse and policy: Adaptation, resilience and vulnerability in a Jamaican agricultural landscape. *Geoforum*, 73, 70-80, doi:10.1016/j.geoforum.2014.11.003.
Portner, H. O. et al., 2021: IPBES-IPCC co-sponsored workshop report on biodiversity and climate change. doi:10.5281/zenodo.4782538.
Povak, N. A. et al., 2020: A decision support tool for the conservation of tropical forest and nearshore environments on Babeldaob Island, Palau. *Forest Ecology and Management*, 476, doi:10.1016/j.foreco.2020.118480.
Prance, F., 2015: Chapter 7: Indigenous ontologies and developmentalism. In: *Environmental Change and the World's Futures: Ecologies, Ontologies and Mythologies* [Marshall, J. and I. Connor (eds.)]. Routledge, London, UK.
Prospero, J. and P. Lamb, 2003: African Droughts and Dust Transport to the Caribbean: Climate Change Implications. *Science*, 302(5647), 1024-1027.
Putman, N. F. et al., 2018: Simulating transport pathways of pelagic Sargassum from the Equatorial Atlantic into the Caribbean Sea. *Progress in Oceanography*, 165, 205-214, doi:10.1016/j.pocean.2018.06.009.
Quataert, E. et al., 2015: The influence of coral reefs on wave-driven flooding of tropical coastlines. *Geophysical Research Letters*, 42, 6407-6415, doi:10.1002/.
Quigley, N., S. Beavis and I. White, 2016: Rainwater harvesting augmentation of domestic water supply in Honiara, Solomon Islands. *Australian Journal of Water Resources*, 20(1), 65-77, doi:10.1080/13241583.2016.1173314.
Raila, E. and D. Anderson, 2017: Healthcare waste management during disasters and its effects on climate change: Lessons from 2010 earthquake and cholera tragedies in Haiti. *Waste Management & Research*, 35(3), 236-245, doi:10.1177/0734242X16682312.
Rambarran, J., 2018: Debt for Climate Swaps: Lessons for Caribbean SIDS from the Seychelles' Experience. *University of the West Indies*, 67(2).
Randall, C. J. and R. van Woesik, 2015: Contemporary white-band disease in Caribbean corals driven by climate change. *Nature Climate Change*, 5(4), 375-379, doi:10.1038/nclimate2530.
Rasmussen, D. et al., 2018: Extreme sea level implications of 1.5 °C, 2.0 °C, and 2.5 °C temperature stabilization targets in the 21st and 22nd centuries. *Environmental Research Letters*, 13(3), doi:10.1088/1748-9326/aaac87.
Ratter, B., J. Petzold and K. Sinane, 2016: Considering the locals: coastal construction and destruction in times of climate change on Anjouan, Comoros. *Natural Resources Forum*, 40(3), 112-126, doi:10.1111/1477-8947.12102.
Ratter, B. M. W., A. Hennig and A. Zahid, 2019: Challenges for shared responsibility - Political and social framing of coastal protection transformation in the Maldives. *Die Erde*, 150(3), 169-183, doi:10.12854/erde-2019-426.
Reguero, B. et al., 2018: Coral reefs for coastal protection: A new methodological approach and engineering case study in Grenada. *Journal of Environmental Management*, 210, 146-161, doi:10.1016/j.jenvman.2018.01.024.
Reguero, B. G. et al., 2020: Financing coastal resilience by combining nature-based risk reduction with insurance. *Ecological Economics*, 169, doi:10.1016/j.ecolecon.2019.106487.
Reimann, L. et al., 2018: Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise. *Nature Communications*, 9(1), 4161, doi:10.1038/s41467-018-06645-9.
Remling, E. and J. Veitayaki, 2016: Community-based action in Fiji's Gau Island: a model for the Pacific? *International Journal of Climate Change Strategies and Management*, 8(3), 375-398, doi:10.1108/ijccsm-07-2015-0101.
Ren, X., Y. Lu, B. O'Neill and M. Weitzel, 2018: Economic and biophysical impacts on agriculture under 1.5 °C and 2 °C warming. *Environmental Research Letters*, 13(11), doi:10.1088/1748-9326/aae6a9.
Renaud, F.G. et al., 2016: *Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice*. Advances in Natural and Technological Hazards Research, Springer International, Cham.
Repolho, T. et al., 2017: Seagrass ecophysiological performance under ocean warming and acidification. *Scientific Reports*, 7, 41443, doi:10.1038/srep41443.
Republic of Maldives, 2009: *Maldives - 4 years after the tsunami: Progress and remaining gaps*, Planning, M. o. F. a. T.-D. o. N., Maldives.
Resiere, D. et al., 2020: Sargassum seaweed health menace in the Caribbean: clinical characteristics of a population exposed to hydrogen sulfide during the 2018 massive stranding. *Clin Toxicol (Phila)*, 59(3), 215-223, doi:10.1080/15563650.2020.1789162.
Resiere, D., H. Mehdaoui, R. Neviere and B. Megarbane, 2019: Sargassum invasion in the Caribbean: the role of medical and scientific cooperation. *Rev Panam Salud Publica*, 43, e52, doi:10.26633/RPSP.2019.52.

Resiere, D. et al., 2018: Sargassum seaweed on Caribbean islands: an international public health concern. *The Lancet*, 392(10165), doi:10.1016/s0140-6736(18)32777-6.
Rey, T., L. Le De, F. Leone and D. Gilbert, 2017: An integrative approach to understand vulnerability and resilience post-disaster: The 2015 cyclone Pam in urban Vanuatu as a case study. *Disaster Prevention and Management: An International Journal*, 26(3), 259-275, doi:10.1108/dpm-07-2016-0137.
Rey, T. et al., 2019: Coastal Processes and Influence on Damage to Urban Structures during Hurricane Irma (St-Martin & St-Barthélemy, French West Indies). *Journal of Marine Science and Engineering*, 7(215), doi:10.3390/jmse7070215.
Rhiney, K., 2020: Dispossession, disaster capitalism and the post-hurricane context in the Caribbean. *Political Geography*, 78, doi:10.1016/j.polgeo.2020.102171.
Rhiney, K., A. Eitzinger, A. Farrell and S. Prager, 2018: Assessing the implications of a 1.5 °C temperature limit for the Jamaican agriculture sector. *Regional Environmental Change*, 18(8), 2313-2327, doi:10.1007/s10113-018-1409-4.
Richardson, B., M. Richardson and G. González, 2018: Responses of Two Litter-Based Invertebrate Communities to Changes in Canopy Cover in a Forest Subject to Hurricanes. *Forests*, 9(6), doi:10.3390/f9060309.
Roberts, E. and S. Huq, 2015: Coming full circle: the history of loss and damage under the UNFCCC. *International Journal of Global Warming*, 8(2), 141-157.
Robinson, J. P. W., S. K. Wilson, S. Jennings and N. A. J. Graham, 2019: Thermal stress induces persistently altered coral reef fish assemblages. *Global Change Biology*, 25(8), 2739-2750, doi:10.1111/gcb.14704.
Robinson, S., 2017a: Climate change adaptation trends in small island developing states. *Mitigation and Adaptation Strategies for Global Change*, 22(4), 669-691, doi:10.1007/s11027-015-9693-5.
Robinson, S., 2017b: Mainstreaming climate change adaptation in small island developing states. *Climate and Development*, 11(1), 47-59, doi:10.1080/17565529.2017.1410086.
Robinson, S., 2018a: Adapting to climate change at the national level in Caribbean small island developing state. *Island Studies Journal*, 13(1), 79-100, doi:10.24043/isj.59.
Robinson, S., 2018b: Climate change adaptation in small island developing states: Insights and lessons from a meta-paradigmatic study. *Environmental Science & Policy*, 85, 172-181, doi:10.1016/j.envsci.2018.03.030.
Robinson, S. and M. Dornan, 2017: International financing for climate change adaptation in small island developing states. *Regional Environmental Change*, 17(4), 1103-1115.
Robinson, S. and D. Gilfillan, 2016: Regional organisations and climate change adaptation in small island developing states. *Regional Environmental Change*, 17(4), 989-1004, doi:10.1007/s10113-016-0991-6.
Rodriguez, F. et al., 2017: "Canary Islands (NE Atlantic) as a biodiversity 'hotspot' of Gambierdiscus: Implications for future trends of ciguatera in the area". *Harmful Algae*, 67, 131-143, doi:10.1016/j.hal.2017.06.009.
Rogers, K. et al., 2019: Wetland carbon storage controlled by millennial-scale variation in relative sea-level rise. *Nature*, 567(7746), 91-95, doi:10.1038/s41586-019-0951-7.
Roland, H. B. and K. J. Curtis, 2020: The differential influence of geographic isolation on environmental migration: a study of internal migration amidst degrading conditions in the central Pacific. *Population and Environment*, 42(2), 161-182, doi:10.1007/s11111-020-00357-3.
Romero-Torres, M. et al., 2020: Coral reef resilience to thermal stress in the Eastern Tropical Pacific. *Global Change Biology*, 26(7), 3880-3890, doi:10.1111/gcb.15126.
Romine, B. and C. Fletcher, 2013: A Summary of Historical Shoreline Changes on Beaches of Kauai, Oahu, and Maui, Hawaii. *Journal of Coastal Research*, 288, 605-614, doi:10.2112/jcoastres-d-11-00202.1.
Rubow, C. and C. Bird, 2016: Eco-theological Responses to Climate Change in Oceania. *Worldviews*, 20(2), 150-168, doi:10.1163/15685357-02002003.
Ruiz, J. M. et al., 2018: Experimental evidence of warming-induced flowering in the Mediterranean seagrass Posidonia oceanica. *Marine Pollution Bulletin*, 134, 49-54, doi:10.1016/j.marpolbul.2017.10.037.
Russell, J. and T. Blackburn, 2017: Invasive Alien Species: Denialism, Disagreement, Definitions, and Dialogue. *Trends in Ecology and Evolution*, 32(5), 312-314, doi:10.1016/j.tree.2017.02.005.
Russell, J., J. Meyer, N. Holmes and S. Pagad, 2017: Invasive alien species on islands: impacts, distribution, interactions and management. *Environmental Conservation*, 44(4), 359-370, doi:10.1017/s0376892917000297.
Ryan, B. et al., 2015: Identifying and Describing the Impact of Cyclone, Storm and Flood Related Disasters on Treatment Management, Care and Exacerbations of Non-communicable Diseases and the Implications for Public Health. *PLoS Currents Disasters*, 7, doi:10.1371/currents.dis.62e9286d152de04799644dcca47d9288.
Sa'adi, Z., S. Shahid, E.-S. Chung and T. b. Ismail, 2017: Projection of spatial and temporal changes of rainfall in Sarawak of Borneo Island using statistical downscaling of CMIP5 models. *Atmospheric Research*, 197, 446-460, doi:10.1016/j.atmosres.2017.08.002.
Saha, C., 2017: Dynamics of climatic and anthropogenic stressors in risking island-char livelihoods: a case of northwestern Bangladesh. *Asian Geographer*, 34(2), 107-129, doi:10.1080/10225706.2017.1354770.
Sainsbury, N. et al., 2018: Changing storminess and global capture fisheries. *Nature Climate Change*, 8(8), 655-659, doi:10.1038/s41558-018-0206-x.
Sainsbury, N. C. et al., 2019: The challenges of extending climate risk insurance to fisheries. *Nature Climate Change*, 9(12), 896-897, doi:10.1038/s41558-019-0645-z.

Saint Ville, A., G. Hickey and L. Phillip, 2015: Addressing food and nutrition insecurity in the Caribbean through domestic smallholder farming system innovation. *Regional Environmental Change*, 15(7), 1325-1339, doi:10.1007/s10113-015-0770-9.
Saintilan, N. et al., 2020: Thresholds of mangrove survival under rapid sea level rise. *Science*, 368, 1118-1121, doi:10.1126/science.aba2656.
Sakhamuri, S. and S. Cummings, 2019: Increasing trans-Atlantic intrusion of Sahara dust: a cause of concern? *The Lancet Planetary Health*, 3(6), e242-e243, doi:10.1016/s2542-5196(19)30088-9.
Salmon, C., V. Duvat and V. Laurent, 2019: Human- and climate-driven shoreline changes on a remote mountainous tropical Pacific Island: Tubuai, French Polynesia. *Anthropocene*, 25, doi:10.1016/j.ancene.2019.100191.
Santos-Burgoa, C. et al., 2018: Differential and persistent risk of excess mortality from Hurricane Maria in Puerto Rico: a time-series analysis. *The Lancet Planetary Health*, 2(11), e478-e488, doi:10.1016/s2542-5196(18)30209-2.
Sasmito, S. D., D. Murdiyarso, D. A. Friess and S. Kurnianto, 2015: Can mangroves keep pace with contemporary sea level rise? A global data review. *Wetlands Ecology and Management*, 24(2), 263-278, doi:10.1007/s11273-015-9466-7.
Savage, A., L. McIver and L. Schubert, 2019: Review: the nexus of climate change, food and nutrition security and diet-related non-communicable diseases in Pacific Island Countries and Territories. *Climate and Development*, 12(2), 120-133, doi:10.1080/17565529.2019.1605284.
Saxena, A., K. Qui and S. Robinson, 2018: Knowledge, attitudes and practices of climate adaptation actors towards resilience and transformation in a 1.5°C world. *Environmental Science & Policy*, 80, 152-159, doi:10.1016/j.envsci.2017.11.001.
Scandurra, G., A. Romano, M. Ronghi and A. Carfora, 2018: On the vulnerability of Small Island Developing States: A dynamic analysis. *Ecological Indicators*, 84, 382-392, doi:10.1016/j.ecolind.2017.09.016.
Schewe, J. et al., 2014: Multimodel assessment of water scarcity under climate change. *Proc Natl Acad Sci U S A*, 111(9), 3245-3250, doi:10.1073/pnas.1222460110.
Schipper, E. et al., 2016: Linking disaster risk reduction, climate change and development. *International Journal of Disaster Resilience in the Built Environment*, 7(2), 216-228, doi:10.1108/ijdrbe-03-2015-0014.
Schipper, E. L. F. et al., 2020: Turbulent transformation: abrupt societal disruption and climate resilient development. *Climate and Development*, 13(6), 467-474, doi:10.1080/17565529.2020.1799738.
Schleicher, J., C. A. Peres and N. Leader-Williams, 2019: Conservation performance of tropical protected areas: How important is management? *Conservation Letters*, 12(5), doi:10.1111/conl.12650.
Schnitter, R. et al., 2019: An Assessment of Climate Change and Health Vulnerability and Adaptation in Dominica. *International Journal of Environmental Research and Public Health*, 16(1), doi:10.3390/ijerph16010070.
Schuhmann, P. W. and R. Mahon, 2015: The valuation of marine ecosystem goods and services in the Caribbean: A literature review and framework for future valuation efforts. *Ecosystem Services*, 11, 56-66, doi:10.1016/j.ecoser.2014.07.013.
Schütte, S. et al., 2018: Connecting planetary health, climate change, and migration. *The Lancet Planetary Health*, 2(2), e58-e59, doi:10.1016/s2542-5196(18)30004-4.
Schwebel, M. B., 2017: Gathering at the AOSIS: perceived cooperation among Pacific Small Island States. *International Environmental Agreements: Politics, Law and Economics*, 18(2), 215-228, doi:10.1007/s10784-017-9379-4.
Schweitzer, M. D. et al., 2018: Lung health in era of climate change and dust storms. *Environmental Research*, 163, 36-42, doi:10.1016/j.envres.2018.02.001.
Scobie, M., 2016: Policy coherence in climate governance in Caribbean Small Island Developing States. *Environmental Science & Policy*, 58, 16-28, doi:10.1016/j.envsci.2015.12.008.
Scott, D., C. Hall and S. Gössling, 2019: Global tourism vulnerability to climate change. *Annals of Tourism Research*, 77, 49-61, doi:10.1016/j.annals.2019.05.007.
Seetanah, B. et al., 2019: Impact of Economic and Financial Development on Environmental Degradation: Evidence from Small Island Developing States (SIDS). *Emerging Markets Finance and Trade*, 55(2), 308-322, doi:10.1080/1540496x.2018.1519696.
Settele, J. et al., 2014: Terrestrial and Inland Water Systems. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, M. D. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, United Kingdom, pp. 271-360. ISBN 9781107415379.
Shah, S., A. Moroca and J. Bhat, 2018: Neo-traditional approaches for ensuring food security in Fiji Islands. *Environmental Development*, 28, 83-100, doi:10.1016/j.envdev.2018.11.001.
Shaig, A., 2008: Settlement planning for natural hazard resilience in small island states: the population and development consolidation approach. James Cook University, Australia.
Shaig, A., 2011: *Survey of Climate Change Adaptation Measure in Maldives*, Ministry of Housing and Environment and United Nationals Development Programme, Maldives.

Shakeela, A. and S. Becken, 2015: Understanding tourism leaders' perceptions of risks from climate change: an assessment of policy-making processes in the Maldives using the social amplification of risk framework (SARF). *Journal of Sustainable Tourism*, 23(1), 65-84, doi:10.1080/09669582.2014.918135.
Sheller, M., 2018: Caribbean Reconstruction and Climate Justice: Transnational Insurgent Intellectual Networks and Post-Hurricane Transformation. *Journal of Extreme Events*, 5(4), 1840001, doi:10.1142/S2345737618400018.
Sheller, M., 2020: Reconstructing tourism in the Caribbean: connecting pandemic recovery, climate resilience and sustainable tourism through mobility justice. *Journal of Sustainable Tourism*, 1-14, doi:10.1080/09669582.2020.1791141.
Shepherd, T., I. Rumengan and A. Sahami, 2018: Post-depositional behaviour of mercury and arsenic in submarine mine tailings deposited in Buyat Bay, North Sulawesi, Indonesia. *Marine Environmental Research*, 137, 88-97, doi:10.1016/j.marenvres.2018.02.028.
Shiels, A., G. González and M. Willig, 2014: Responses to canopy loss and debris deposition in a tropical forest ecosystem: Synthesis from an experimental manipulation simulating effects of hurricane disturbance. *Forest Ecology and Management*, 332, 124-133, doi:10.1016/j.foreco.2014.08.005.
Shope, J. and C. Storlazzi, 2019: Assessing Morphologic Controls on Atoll Island Alongshore Sediment Transport Gradients Due to Future Sea-Level Rise. *Frontiers in Marine Science*, 6, doi:10.3389/fmars.2019.00245.
Shope, J., C. Storlazzi, L. Erikson and C. Hegermiller, 2016: Changes to extreme wave climates of islands within the Western Tropical Pacific throughout the 21st century under RCP 4.5 and RCP 8.5, with implications for island vulnerability and sustainability. *Global and Planetary Change*, 141, 25-38, doi:10.1016/j.gloplacha.2016.03.009.
Shope, J., C. Storlazzi and R. Hoeke, 2017: Projected atoll shoreline and run-up changes in response to sea-level rise and varying large wave conditions at Wake and Midway Atolls, Northwestern Hawaiian Islands. *Geomorphology*, 295, 537-550, doi:10.1016/j.geomorph.2017.08.002.
Short, F. et al., 2016: Impacts of climate change on submerged and emergent wetland plants. *Aquatic Botany*, 135, 3-17, doi:10.1016/j.aquabot.2016.06.006.
Shultz, J. M. et al., 2018: Hurricane Risks, Health Consequences, and Response Challenges for Small island Based Populations: Observations from the 2017 Atlantic Hurricane Season. *Disaster Medicine and Public Health Preparedness*, 13(1), 5-17, doi:10.1017/dmp.2018.28.
Shutter, A., 2020: Barbados Sovereign Debt Restructuring 2018-2019—Like the island, small but perfectly formed. *Capital Markets Law Journal*, 15(2), 250-257, doi:10.1093/cmlj/kmaa006.
Siegel, K. J. et al., 2019: Sovereign states in the Caribbean have lower social-ecological vulnerability to coral bleaching than overseas territories. *Proc Biol Sci*, 286(1897), 20182365, doi:10.1098/rspb.2018.2365.
Singeo, A., 2011: *Teaching Indigenous Knowledge towards Environmental Conservation: A Case Study of Camp Ebiil in Palau*. EIU Best Practices, 22, Asia Pacific Centre of Education for International Understanding, Seoul, South Korea, 47 pp.
Singh-Peterson, L. and M. Iranacolaivalu, 2018: Barriers to market for subsistence farmers in Fiji – A gendered perspective. *Journal of Rural Studies*, 60, 11-20, doi:10.1016/j.jrurstud.2018.03.001.
Sippo, J. Z. et al., 2018: Mangrove mortality in a changing climate: An overview. *Estuarine, Coastal and Shelf Science*, 215, 241-249, doi:10.1016/j.ecss.2018.10.011.
Smith, J. et al., 2017: Malaria early warning tool: linking inter-annual climate and malaria variability in northern Guadalcanal, Solomon Islands. *Malaria Journal*, 16(1), 472, doi:10.1186/s12936-017-2120-5.
Smith, R. and K. Rhiney, 2016: Climate (in)justice, vulnerability and livelihoods in the Caribbean: The case of the indigenous Caribs in northeastern St. Vincent. *Geoforum*, 73, 22-31, doi:10.1016/j.geoforum.2015.11.008.
Smith, S., Environmental Levy Takes Effect September 1, Government of the British Virgin Islands, British Virgin Islands. Available at: https://www.bvitourism.com/news/environmental-levy-takes-effect-september-1.
Smithers, S. and R. Hoeke, 2014: Geomorphological impacts of high-latitude storm waves on low-latitude reef islands — Observations of the December 2008 event on Nukutoa, Takuu, Papua New Guinea. *Geomorphology*, 222, 106-121, doi:10.1016/j.geomorph.2014.03.042.
Sofer, M., 2015: Kadavu Island: adaptation and stagnation in the Fijian periphery. *Miscellanea Geographica*, 19(2), 14-20, doi:10.1515/mgrsd-2015-0006.
Spalding, M. and B. Brown, 2015: Warm-water coral reefs and climate change. *Science*, 350(6262), 769-771, doi:10.1126/science.aad0349.
Spatz, D. et al., 2017a: Globally threatened vertebrates on islands with invasive species. *Science Advances*, 3(e1603080), doi:10.1126/sciadv.1603080.
Spatz, D. R. et al., 2017b: Managing Invasive Mammals to Conserve Globally Threatened Seabirds in a Changing Climate. *Conservation Letters*, 10(6), 736-747, doi:10.1111/conl.12373.
SPC, 2016: *Framework for Resilient Development in the Pacific: An Integrated Approach to Address Climate Change and Disaster Risk Management (FRDP) 2017-2030*.
SPC, 2019: *Policy Brief: Implications of climate-driven redistribution of tuna for Pacific Island economies*. Pacific Community, Noumea, New Caledonia, 4 pp.
SPREP, 2016a: *Pacific Islands Meteorological Services in Action : a compendium of climate services case studies*. SPREP, Samoa.
SPREP, 2016b: *Vanuatu Framework for Climate Services* [Tait, A. and G. Macara (eds.)]. National Institute of Water and Atmospheric Research, New Zealand.

SPREP, 2017: Pacific Roadmap for Strengthening Climate Services 2017-2026.
Springmann, M. et al., 2016: Global and regional health effects of future food production under climate change: a modelling study. *The Lancet*, 387(10031), 1937-1946, doi:10.1016/s0140-6736(15)01156-3.
Stennett-Brown, R., J. Jones, T. Stephenson and M. Taylor, 2017: Future Caribbean temperature and rainfall extremes from statistical downscaling. *International Journal of Climatology*, 37(14), 4828-4845, doi:10.1002/joc.5126.
Stephenson, T. et al., 2014: Changes in extreme temperature and percipitation in the Caribbean region, 1961-2010. *International Journal of Climatology*, 34, 2957-2971, doi:10.1002/joc.3889.
Stojanov, R. et al., 2017: Local perceptions of climate change impacts and migration patterns in Malé, Maldives. *The Geographical Journal*, 183(4), 370-385, doi:10.1111/geoj.12177.
Storey, D. and S. Hunter, 2010: Kiribati: an environmental 'perfect storm'. *Australian Geographer*, 41(2), 167-181, doi:10.1080/00049181003742294.
Storlazzi, C. et al., 2018: Most atolls will be uninhabitable by the mid-21st century because of seal-level rise exacerbating wave-driven flooding. *Science Advances*, 4, eaap9741, doi:10.1126/sciadv.aap9741.
Strauch, A. M. et al., 2014: Climate change and land use drivers of fecal bacteria in tropical hawaiian rivers. *Journal of Environmental Quality*, 43(4), 1475-1483, doi:10.2134/jeq2014.01.0025.
Strauch, A. M., R. A. MacKenzie, C. P. Giardina and G. L. Bruland, 2015: Climate driven changes to rainfall and streamflow patterns in a model tropical island hydrological system. *Journal of Hydrology*, 523, 160-169, doi:10.1016/j.jhydrol.2015.01.045.
Struebig, M. et al., 2015a: Targeted conservation to safeguard a biodiversity hotspot from climate and land-cover change. *Current Biology*, 25(3), 372-378, doi:10.1016/j.cub.2014.11.067.
Struebig, M. J. et al., 2015b: Anticipated climate and land-cover changes reveal refuge areas for Borneo's orang-utans. *Global Change Biology*, 21(8), 2891-2904, doi:10.1111/gcb.12814.
Suaalii-Sauni, T. and S. Fulu-Aiolupotea, 2014: Decolonising Pacific research, building Pacific research communities and developing Pacific research tools: The case of the talanoa and the faafaletui in Samoa. *Asia Pacific Viewpoint*, 55(3), 331-344, doi:10.1111/apv.12061.
Suliman, S. et al., 2019: Indigenous (im)mobilities in the Anthropocene. *Mobilities*, 14(3), 298-318, doi:10.1080/17450101.2019.1601828.
Sully, S. et al., 2019: A global analysis of coral bleaching over the past two decades. *Nature Communications*, 10(1), 1264, doi:10.1038/s41467-019-09238-2.
Sunday, J. M. et al., 2016: Ocean acidification can mediate biodiversity shifts by changing biogenic habitat. *Nature Climate Change*, 7(1), 81-85, doi:10.1038/nclimate3161.
Tabe, T., 2019: Climate Change Migration and Displacement: Learning from Past Relocations in the Pacific. *Social Sciences*, 8(218), doi:10.3390/socsci8070218.
Taherkhani, M. et al., 2020: Sea-level rise exponentially increases coastal flood frequency. *Scientific Reports*, 10(1), 6466, doi:10.1038/s41598-020-62188-4.
Taillie, P. et al., 2020: Widespread mangrove damage resulting from the 2017 Atlantic mega hurricane season. *Environmental Research Letters*, 15(064010), doi:10.1088/1748-9326/ab82cf.
Tapsuwan, S. and W. Rongrongmuang, 2015: Climate change perception of the dive tourism industry in Koh Tao island, Thailand. *Journal of Outdoor Recreation and Tourism*, 11, 58-63, doi:10.1016/j.jort.2015.06.005.
Taupo, T., H. Cuffe and I. Noy, 2018: Household vulnerability on the frontline of climate change: the Pacific atoll nation of Tuvalu. *Environmental Economics and Policy Studies*, 20(4), 705-739, doi:10.1007/s10018-018-0212-2.
Tauvale, L. and K. Tsuboki, 2019: Characteristics of Tropical Cyclones in the Southwest Pacific. *Journal of the Meteorological Society of Japan. Ser. II*, 97(3), 711-731, doi:10.2151/jmsj.2019-042.
Taylor, A. and K. Kumar, 2016a: Global Climate Change Impacts on Pacific Islands Terrestrial Biodiversity: a review. *Tropical Conservation Science*, 9(1), 203-223, doi:10.1177/194008291600900111.
Taylor, M. et al., 2018: Future Caribbean Climates in a World of Rising Temperatures: The 1.5 vs 2.0 Dilemma. *Journal of Climate*, 31(7), 2907-2926, doi:10.1175/jcli-d-17-0074.1.
Taylor, N. A. S., J. Y. Lee, S. Kim and S. R. Notley, 2021: Physiological interactions with personal-protective clothing, physically demanding work and global warming: An Asia-Pacific perspective. *Journal of Thermal Biology*, 97, 102858, doi:10.1016/j.jtherbio.2021.102858.
Taylor, S. and L. Kumar, 2016b: Will climate change impact the potential distribution of a native vine (Merremia peltata) which is behaving invasively in the Pacific region? *Ecology and Evolution*, 6(3), 742-754, doi:10.1002/ece3.1915.
Taylor, S. F. W., M. J. Roberts, B. Milligan and R. Ncwadi, 2019: Measurement and implications of marine food security in the Western Indian Ocean: an impending crisis? *Food Security*, 11(6), 1395-1415, doi:10.1007/s12571-019-00971-6.
Techera, E., 2018: Supporting blue economy agenda: fisheries, food security and climate change in the Indian Ocean. *Journal of the Indian Ocean Region*, 14(1), 7-27, doi:10.1080/19480881.2017.1420579.
Terry, J. and T. Chui, 2012: Evaluating the fate of freshwater lenses on atoll islands after eustatic sea-level rise and cyclone-driven inundation: A modelling approach. *Global and Planetary Change*, 88-89, 76-84, doi:10.1016/j.gloplacha.2012.03.008.
Tershy, B. et al., 2015: The Importance of Islands for the Protection of Biological and Linguistic Diversity. *BioScience*, 65(6), doi:10.1093/biosci/biv031.

Teurlai, M. et al., 2015: Socio-economic and Climate Factors Associated with Dengue Fever Spatial Heterogeneity: A Worked Example in New Caledonia. *PLoS Neglected Tropical Diseases*, 9(12), e0004211, doi:10.1371/journal.pntd.0004211.
Thiault, L. et al., 2018: Mapping social-ecological vulnerability to inform local decision making. *Conservation Biology*, 32(2), 447-456, doi:10.1111/cobi.12989.
Thomas, A. and L. Benjamin, 2017: Management of loss and damage in small island developing states: implications for a 1.5 °C or warmer world. *Regional Environmental Change*, 18(8), 2369-2378, doi:10.1007/s10113-017-1184-7.
Thomas, A. and L. Benjamin, 2018a: Perceptions of climate change risk in The Bahamas. *Journal of Environmental Studies and Sciences*, 8(1), 63-72, doi:10.1007/s13412-017-0429-6.
Thomas, A. and L. Benjamin, 2018b: Policies and mechanisms to address climate-induced migration and displacement in Pacific and Caribbean small island developing states. *International Journal of Climate Change Strategies and Management*, 10(1), T86-104, doi:10.1108/IJCCSM-03-2017-0055.
Thomas, A. and L. Benjamin, 2019: Non-economic loss and damage: lessons from displacement in the Caribbean. *Climate Policy*, 1-14, doi:10.1080/14693062.2019.1640105.
Thomas, A., O. Serdeczny and P. Pringle, 2020: Loss and damage research for the global stocktake. *Nature Climate Change*, 10(8), 700-700, doi:10.1038/s41558-020-0807-z.
Thomas, A. et al., 2021: Global evidence of constraints and limits to human adaptation. *Regional Environmental Change*, 21(3), doi:10.1007/s10113-021-01808-9.
Thomson, L., R. Thaman and F. Anna, 2016: Chapter 8: Native forests, plantation forests and trees outside forests: their vulnerability and roles in mitigating and building resilience to climate Change. In: *Vulnerability of Pacific Agriculture and Forestry to Climate Change* [Taylor, M., A. McGregor and B. Dawson (eds.)]. Secretariat of the Pacific Community, New Caledonia, pp. 383-446.
Ticktin, T. et al., 2018: Linkages between measures of biodiversity and community resilience in Pacific Island agroforests. *Conservation Biology*, 32(5), 1085-1095, doi:10.1111/cobi.13152.
Tietze, U. and R. van Anrooy, 2018: *Assessment of insurance needs and opportunities in the Caribbean fisheries sector*. FAO FIsheries and Aquaculture Circular No. 1175, Food and Agriculture Organization of the United Nations, Rome, Italy, 62 pp.
Timm, E., T. Giambelluca and H. Diaz, 2015: Statistical downscaling of rainfall changes in Hawai'i based on the CMIP5 global model projections. *Journal of Geophysical Research: Atmospheres*, 120, 92-112, doi:10.1002/2014JD022059.
Townhill, B. L. et al., 2021: Climate Change Impacts on Atlantic Oceanic Island Tuna Fisheries. *Frontiers in Marine Science*, 8, doi:10.3389/fmars.2021.634280.
Traylor, J. and M. Singhal, 2020: Ciguatera Toxicity. In: *StatPearls [Internet]*. StatPearls Publishing.
Trotman, A. et al., 2017: Chapter 20: Drought Risk Management in the Caribbean Community: Early Warning Information and Other Risk Reduction Considerations. In: *Drought and Water Crises: Integrating science, management, and policy* [Wilhite, D. and R. Pulwarty (eds.)]. Taylor and Francis Group, Boca Raton.
Trotman, A. et al., 2018: Strengthening Climate Services for the Health Sector in the Caribbean. *World Meteorological Organization Bulletin*, 67(2).
Trundle, A., B. Barth and D. McEvoy, 2018: Leveraging endogenous climate resilience: urban adpatation in Pacific Small Island Developing States. *Environment and Urbanization*, 31(1), 53-74, doi:10.1177/0956247818816654.
Tserkezis, E. and A. Tsakanikas, 2016: The economic impact of mining activity on the Greek island of Milos: An unusual neighbor. *The Extractive Industries and Society*, 3(1), 129-140, doi:10.1016/j.exis.2015.10.007.
Tuck, M., P. Kench, M. Ford and G. Masselink, 2019: Physical modelling of the response of reef islands to sea level rise. *Geology*, 47(9), doi:10.1130/G46362.1.
Turner, R., P. McConney and I. Monnereau, 2020: Climate Change Adaptation and Extreme Weather in the Small-Scale Fisheries of Dominica. *Coastal Management*, 48(5), 436-455, doi:10.1080/08920753.2020.1795970.
Umeyama, M., 2012: Shore Protection against Sea Level Rise and Tropical Cyclones in Small Island States. *Natural Hazards Review*, 13(2), 106-116, doi:10.1061/(asce)nh.1527-6996.0000052.
UN, 2015a: *Paris Agreement*. Available at: https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
UN, 2015b: *Sendai Framework for Disaster Risk Reduction 2015-2030.* Available at: https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf.
UN, 2015c: *Transforming our world: the 2030 Agenda for Sustainable Development.* Available at: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.
UNEP, 2014a: *Emerging issues for Small Island Developing States. Results of the UNEP/UN DESA Foresight Process*. United Nations Environment Programme, Nairobi, Kenya.
UNEP, 2014b: *The importance of mangroves to people: A call to action* [van Bochove, J., E. Sullivan and T. Nakamura (eds.)]. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge. ISBN 978-92-807-3397-6.
Vafeidis, A. et al., 2019: Water-level attenuation in global-scale assessments of exposure to coastal flooding: a sensitivity analysis. *Natural Hazards and Earth System Sciences*, 19(5), 973-984, doi:10.5194/nhess-19-973-2019.
Van Beusekom, A. et al., 2018: Hurricane Maria in the U.S. Caribbean: Disturbance Forces, Variation of Effects, and Implications for Future Storms. *Remote Sensing*, 10(9), doi:10.3390/rs10091386.

van den Burg, M. P., J. L. K. Brisbane and C. R. Knapp, 2020: Post-hurricane relief facilitates invasion and establishment of two invasive alien vertebrate species in the Commonwealth of Dominica, West Indies. *Biological Invasions*, 22(2), 195-203, doi:10.1007/s10530-019-02107-5.
van der Veeken, S. et al., 2016: Tourism destinations' vulnerability to climate change: Nature-based tourism in Vava'u, the Kingdom of Tonga. *Tourism and Hospitality Research*, 16(1), 50-71, doi:10.1177/1467358415611068.
van Hooidonk, R. et al., 2016: Local-scale projections of coral reef futures and implications of the Paris Agreement. *Scientific Reports*, 6, 39666, doi:10.1038/srep39666.
van Kleunen, M. et al., 2015: Global exchange and accumulation of non-native plants. *Nature*, 525(7567), 100-103, doi:10.1038/nature14910.
van Tussenbroek, B. et al., 2017: Severe impacts of brown tides caused by Sargassum spp. on near-shore Caribbean seagrass communities. *Marine Pollution Bulletin*, 122(1-2), 272-281, doi:10.1016/j.marpolbul.2017.06.057.
Varela, M. et al., 2019: Assessing climate change associated sea level rise impacts on sea turtle nesting beaches using drones, photogrammetry and a novel GPS system. *Global Change Biology*, 25(2), 753-762, doi:10.1111/gcb.14526.
Varotsos, K. V. et al., 2021: Near future climate change projections with implications for the agricultural sector of three major Mediterranean islands. *Regional Environmental Change*, 21(1), doi:10.1007/s10113-020-01736-0.
Vaughan, C. and S. Dessai, 2014: Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. *WIREs Climate Change*, 5(5), 587-603, doi:10.1002/wcc.290.
Vaughan, C., S. Dessi and C. Hewitt, 2018: Surveying Climate Services: What Can We Learn from a Bird's-Eye View? *Weather, Climate, and Society*, 10, 373-395, doi:10.1175/WCAS-D-17-0030.1.
Veelenturf, C. A., E. M. Sinclair, F. V. Paladino and S. Honarvar, 2020: Predicting the impacts of sea level rise in sea turtle nesting habitat on Bioko Island, Equatorial Guinea. *PLoS One*, 15(7), e0222251, doi:10.1371/journal.pone.0222251.
Vincent, K. and T. Cull, 2014: Using Indicators to Assess Climate Change and Vulnerabilities: Are There Lessons to Lear from Emerging Loss and Damage Debates? *Geography Compass*, 8(1), 1-12, doi:10.1111/gec3.12105.
Virah-Sawmy, M. et al., 2016: A landscape vulnerability framework for identifying integrated conservation and adaptation pathways to climate change: the case of Madagascar's spiny forest. *Landscape Ecology*, 31(3), 637-654, doi:10.1007/s10980-015-0269-2.
Vitousek, S. et al., 2017: Doubling of coastal flooding frequency within decades due to sea-level rise. *Scientific Reports*, 7(1), 1399, doi:10.1038/s41598-017-01362-7.
Vogiatzakis, I., A. Mannion and D. Sarris, 2016: Mediterranean island biodiversity and climate change: the last 10,000 years and the future. *Biodiversity and Conservation*, 25(13), 2597-2627, doi:10.1007/s10531-016-1204-9.
Volz, U. et al., 2020: *Climate Change and Sovereign Risk*. SOAS University of London, Asian Development Bank Institute, World Wide Fund for Nature Singapore, Four Twenty Seven, London, UK.
Vorsino, A. E. et al., 2014: Modeling Hawaiian ecosystem degradation due to invasive plants under current and future climates. *PLoS One*, 9(5), e95427, doi:10.1371/journal.pone.0095427.
Vousdoukas, M. et al., 2020: Sandy coastlines under threat of erosion. *Nature Climate Change*, 10, 260-263, doi:10.1038/s41558-020-0697-0.
Wabnitz, C., A. Cisneros-Montemayor, Q. Hanich and Y. Ota, 2018: Ecotourism, climate change and reef fish consumption in Palau: Benefits, trade-offs and adaptation strategies. *Marine Policy*, 88, 323-332, doi:10.1016/j.marpol.2017.07.022.
Wadey, M., S. Brown, R. Nicholls and I. Haigh, 2017: Coastal flooding in the Maldives: an assessment of historic events and their implications. *Natural Hazards*, 89(1), 131-159, doi:10.1007/s11069-017-2957-5.
Wairiu, M., 2017: Land degradation and sustainable land management practices in Pacific Island Countries. *Regional Environmental Change*, 17(4), 1053-1064, doi:10.1007/s10113-016-1041-0.
Waite, R., L. Burke and E. Gray, 2014: *Coastal Capital: Ecosystem Valuation for Decision Making in the Caribbean*. World Resources Institute, Washington, D.C. Available at: http://www.wri.org/coastal-capital.
Walcker, R. et al., 2019: Damages caused by hurricane irma in the human-degraded mangroves of Saint Martin (Caribbean). *Scientific Reports*, 9(18971), doi:10.1038/s41598-019-55393-3.
Walsh, K. et al., 2016: Tropical cyclones and climate change. *Wiley Interdisciplinary Reviews-Climate Change*, 7(1), 65-89, doi:doi:10.1002/wcc.371.
Wandres, M. et al., 2020: Distant-Source Swells Cause Coastal Inundation on Fiji's Coral Coast. *Frontiers in Marine Science*, 7, doi:10.3389/fmars.2020.00546.
Wang, M. et al., 2019: The great Atlantic Sargassum belt. *Science*, 365, 83-87, doi:10.1126/science.aaw7912.
Warix, S., L. Rademacher and M. Stege, 2017: Groundwater Resource Vulnerability to Climate Change: Outer Atolls of the Republic of the Marshall Islands.
Warren, R. et al., 2018a: The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5C rather than 2C. *Science*, 360, 791-795, doi:10.1126/science.aar3646.
Warren, R. et al., 2018b: The implications of the United Nations Paris Agreement on climate change for globally significant biodiversity areas. *Climatic Change*, 147(3-4), 395-409, doi:10.1007/s10584-018-2158-6.
Warrick, O. et al., 2017: The 'Pacific Adaptive Capacity Analysis Framework': guiding the assessment of adaptive capacity in Pacific island communities. *Regional Environmental Change*, 17(4), 1039-1051, doi:10.1007/s10113-016-1036-x.

Waycott, M. et al., 2009: Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *PNAS*, 106(30), 12377-12381, doi:10.1073/pnas.0905620106.
Waycott, M. et al., 2011: Chapter 6: Vulnerability of mangroves, sesagrasses and intertidal flats in the tropical Pacific to climate change. In: *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change.* [Bell, J., J. E. Johnson and A. J. Hobday (eds.)]. Secretariat of the Pacific Community, pp. 297-368.
Weatherdon, L. et al., 2016: Observed and Projected Impacts of Climate Change on Marine Fisheries, Aquaculture, Coastal Tourism, and Human Health: An Update. *Frontiers in Marine Science*, 3(48), doi:10.3389/fmars.2016.00048.
Webb, A. and P. Kench, 2010: The dynamic response of reef islands to sea-level rise: Evidence from multi-decadal analysis of island change in the Central Pacific. *Global and Planetary Change*, 72(3), 234-246, doi:10.1016/j.gloplacha.2010.05.003.
Webb, J. et al., 2015: Tools for CBA: Lessons from NGO Collaboration in Vanuatu. *Coastal Management*, 43(4), 407-423, doi:10.1080/08920753.2015.1046807.
Weber, E., 2016a: Only a pawn in their games? Environmental (?) migration in Kiribati - past, present and future. *Die Erde*, 147(2), 153-164, doi:10.12854/erde-147-11.
Weber, E., 2016b: Trade agreements, labour mobility and climate change in the Pacific Islands. *Regional Environmental Change*, 17(4), 1089-1101, doi:10.1007/s10113-016-1047-7.
Weiler, F., C. Klöck and M. Dornan, 2018: Vulnerability, good governance, or donor interests? The allocation of aid for climate change adaptation. *World Development*, 104, 65-77, doi:10.1016/j.worlddev.2017.11.001.
Weir, T., 2018: Renewable energy in the Pacific Islands: Its role and status. *Renewable and Sustainable Energy Reviews*, 94, 762-771, doi:10.1016/j.rser.2018.05.069.
Weir, T., 2020: Adaptation in Small Islands: Research Themes and Gaps. In: *Managing Cliamte Change Adaptation in the Pacific Region* [Filho, W. L. (ed.)]. Springer, Cham, pp. 45-67.
Weir, T., L. Dovey and D. Orcherton, 2017: Social and cultural issues raised by climate change in Pacific Island countries: an overview. *Regional Environmental Change*, 17(4), 1017-1028, doi:10.1007/s10113-016-1012-5.
Weir, T. and M. Kumar, 2020: Renewable energy can enhance resilience of small islands. *Natural Hazards*, 1-7, doi:10.1007/s11069-020-04266-4.
Weir, T. and J. Pittock, 2017: Human dimensions of environmental change in small island developing states: some common themes. *Regional Environmental Change*, 17(4), 949-958, doi:10.1007/s10113-017-1135-3.
Weissenberger, S., 2018: Haïti: vulnérabilité, résilience et changements climatiques. *Haiti Perspectives*, 6(3), 19-26.
Wetzel, F., H. Beissmann, D. Penn and W. Jetz, 2013: Vulnerability of terrestrial island vertebrates to projected sea-level rise. *Global Change Biology*, 19(7), 2058-2070, doi:10.1111/gcb.12185.
Wetzel, F., W. Kissling, H. Beissmann and D. Penn, 2012: Future climate change driven sea-level rise: secondary consequences from human displacement for island biodiversity. *Global Change Biology*, 18(9), 2707-2719, doi:10.1111/j.1365-2486.2012.02736.x.
WHO, 2015: *Operational framework for building climate resilient health systems*. World Health Organization, Geneva.
WHO, 2018: *Climate change and health in small island developing nations: a WHO special initiative*. World Health Organizations, Geneva.
WHO, 2020: *WHO Guidance for Climate-Resilient and Environmentally Sustainable Health Care Facilities*. Wold Health Organization, Geneva.
Williams, D., S. Rosendo, O. Sadasing and L. Celliers, 2020: Identifying local governance capacity needs for implementing climate change adaptation in Mauritius. *Climate Policy*, 20(5), 548-562, doi:10.1080/14693062.2020.1745743.
Wilson, A. and C. Forsyth, 2018: Restoring near-shore marine ecosystems to enhance climate security for island ocean states: Aligning international processes and local practices. *Marine Policy*, 93, 284-294, doi:10.1016/j.marpol.2018.01.018.
Wilson, K., 2013: Wan laki aelan? Diverse development strategies on Aniwa, Vanuatu. *Asia Pacific Viewpoint*, 54(2), 246-263, doi:10.1111/apv.12012.
Wilson, R., 2017: Impacts of Climate Change on Mangrove Ecosystems in the Coastal and Marine Environments of Caribbean Small Island Developing States (SIDS). *Caribbean Marine Climate Change Report Card: Science Review 2017.*, 61-82.
WMO, 2014: *Implementation Plan of the Global Framework for Climate Services*. Switzerland.
WMO, 2019: Global Framework for Climate Services (GFCS) Implementation in Dominica. Available at: https://gfcs.wmo.int.
WMO, 2019: Programme for building regional climate capacity in the Caribbean. Available at: https://public.wmo.int/en/projects/program-building-regional-climate-capacity-caribbean.
WMO, 2019: Implementing the Global Framework for Climate Services at Regional and National Scales. Available at: https://public.wmo.int/en/projects/implementing-global-framework-climate-services-gfcs-regional-and-national-scales.
WMO, 2019: Multi-Hazard Early Warning Systems (MHEWS). Available at: https://www.wmo.int/pages/prog/drr/projects/Thematic/MHEWS/MHEWS_en.html.
WMO, 2020: *2020 State of Climate Services: Risk Information and Early Warning Systems*. Available at: https://library.wmo.int/doc_num.php?explnum_id=10385.

WMO, UNDRR and WB, 2018: *Caribbean 2017 Hurricane Season: an evidence-based assessment of the Early Warning System*. WMO, Switzerland. Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/2018_wmo_crews-caribbean-report_en.pdf.
Woesik, R. et al., 2012: Climate-change refugia in the sheltered bays of Palau: analogs of future reefs. *Ecology and Evolution*, 2(10), 2474-2484, doi:10.1002/ece3.363.
Wolcott, D., D. Donner, D. Brown and C. Ribic, 2018: Kirtland's Warbler Winter Habitat Changes Across the Bahamian Archipelago in Response to Future Climate-condition Scenarios. *Caribbean Naturalist*, 49, 1-20.
Woodhead, A. et al., 2019: Coral reef ecosystem services in the Anthropocene. *Functional Ecology*, 33, doi:10.1111/1365-2435.13331.
World Bank, 2016: *Managing Coasts with Natural Solutions: Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs.*, Wealth Accounting and the Valuation of Ecosystem Services Partnership (WAVES), World Bank, Washington, D.C.
Yamano, H. et al., 2007: Atoll island vulnerability to flooding and inundation revealed by historical reconstruction: Fongafale Islet, Funafuti Atoll, Tuvalu. *Global and Planetary Change*, 57(3-4), 407-416, doi:10.1016/j.gloplacha.2007.02.007.
Yang, Z., T. Wang, N. Voisin and A. Copping, 2015: Estuarine response to river flow and sea-level rise under future climate change and human development. *Estuarine, Coastal and Shelf Science*, 156, 19-30, doi:10.1016/j.ecss.2014.08.015.
Yoshida, K. et al., 2017: Future Changes in Tropical Cyclone Activity in High-Resolution Large-Ensemble Simulations. *Geophysical Research Letters*, 44(19), 9910-9917, doi:10.1002/2017gl075058.
Zahid, A. et al., 2018: Chapter 32: Model Impact of Climate Change on the Groundwater Flow and Salinity Encroachment in the Coastal Areas of Bangladesh. In: *Groundwater of South Asia* [Mukherjee, A. (ed.)]. Springer Hydrogeography, pp. 545-568. ISBN 978-981-10-3888-4.
Zheng, L. et al., 2020: Modeling the time-lag effect of sea surface temperatures on ciguatera poisoning in the South Pacific: Implications for surveillance and response. *Toxicon*, 182, 21-29, doi:10.1016/j.toxicon.2020.05.001.