Cross-Chapter Paper 2: Cities and Settlements by the Sea

Cross-Chapter Paper Leads: Bruce Glavovic (New Zealand/South Africa), Richard Dawson (United Kingdom), Winston Chow (Singapore)

Cross-Chapter Paper Authors: Matthias Garschagen (Germany), Marjolijn Haasnoot (The Netherlands), Chandni Singh (India), Adelle Thomas (Bahamas)

Cross-Chapter Paper Contributing Authors: Jeroen Aerts (The Netherlands), Sophie Blackburn (United Kingdom), David Catt (USA), Eric Chu (USA), William Solecki (USA), Stijn-Temmerman (Belgium), Gundula Winter (Germany)

Cross-Chapter Paper Review Editor: Soojeong Myeong (Republic of Korea)

Cross-Chapter Paper Scientist: David Catt (USA)

Date of Draft: 1 October 2021

Notes: TSU Compiled Version

Table of Contents

Executive Summary

Cities and settlements by the sea (C&S) are on the frontline of climate change – they face amongst the highest climate-compounded risks but are a key source of innovations in climate resilient development (*high confidence*[1]) {Sections 6.1, 6.2; Chapter 7, Box 15.2; Cross-Chapter Box –COVID in Chapter 7; Cross-Chapter Box –SLR in Chapter 3; CCP2.2; SMCCP2.1; WGI Section 12.4.10.2}.

Much of the world's population, economic activities and critical infrastructure are concentrated near the sea (*high confidence*), with nearly 11% of the global population, or 896 million people, already living on low-lying coasts directly exposed to interacting climate- and non-climate coastal hazards (*very high confidence*) {CCP2.1}. Low-lying C&S are experiencing adverse climate impacts that are superimposed on extensive and accelerating anthropogenic coastal change (*very high confidence*) {WGI Section 12.4.10.2; Sections 6.1, 6.2; CCP2.2, SMCCP2.1}. Depending on coastal C&S characteristics, continuing existing patterns of coastal development will worsen exposure and vulnerability (*high confidence*) {CCP2.1}. With accelerating sea level rise (SLR) and worsening climate-driven risks in a warming world, prospects for achieving the Sustainable Development Goals (SDGs) and charting Climate Resilient Development (CRD) pathways are dismal (*high confidence*) {CCP2.3, CCP2.4; Chapter 16, 18}. However, coastal C&S are also the source of SDG and CRD solutions because they are centres of innovation with long histories of place-based livelihoods, many of which are globally connected through maritime trade and exchange (*medium confidence*) {CCP2.4}.

Regardless of climate and socio-economic scenarios, many C&S face severe disruption to coastal ecosystems and livelihoods by 2050 – and across all C&S by 2100 and beyond – caused by compound and cascading risks, including submergence of some low-lying island states (*very high confidence*) {CCP2.1; CCP2.2; SROCC SPM, Chapter 4; Section 6.2}.

There is *high confidence* that projected climate risks will increase with (i) exposure to climate- and ocean-driven hazards manifest at the coast, such as heat waves, droughts, pluvial floods, and impacts due to SLR, tropical cyclones, marine and land heatwaves, and ocean acidification; (ii) with increasing vulnerability driven by inequity, and (iii) increasing exposure driven by urban growth in at-risk locations. Compounded and cascading climate risks, such as to coastal C&S infrastructure and supply chain networks, are also expected to increase {Section 6.2.7; CCP2.2}. These risks are acute for C&S on subsiding and/or low-lying small islands, the Arctic, and open, estuarine and deltaic coasts (*high confidence*) {CCP2.2; Table SMCCP2.1}. By 2050, more than a billion people located in low-lying C&S will be at risk from coast-specific climate hazards, influenced by coastal geomorphology, geographical location and adaptation action (*high confidence*). Between US$7-14 trillion of coastal infrastructure assets will be exposed by 2100, depending on warming levels and socio-economic development trajectories (*medium confidence*) {CCP2.1}. Historically rare extreme sea level events will occur annually by 2100, with some atolls being uninhabitable by 2050. Coastal flood risk rapidly increases in coming decades, and could increase by 2–3 orders of magnitude by 2100 in the absence of effective adaptation and mitigation, with severe impacts on coast-dependent livelihoods and socio-ecological systems (*high confidence*) {SROCC SPM; Chapter 4}. Impacts reach far beyond C&S e.g., damage to ports severely compromising global supply chains and maritime trade with local-global geo-political and economic ramifications. Global investment costs to accommodate port growth and adapt to SLR amount to USD223-768 billion before 2050, presenting opportunities for C&S by the sea to build climate resilience (*medium evidence, high agreement*) {CCP2.1; CCP2.2; Cross-Chapter Box SLR in Chapter 3}. Severely accelerated SLR resulting from rapid continental ice mass-loss would bring impacts forward by decades, and adaptation would need to occur much faster and at much greater scale than ever done in the past (*medium confidence*).

[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.

A mix of interventions is necessary to manage coastal risks and build resilience over time. An adaptation pathways approach sets out near-term 'low-regret' actions that align with societal goals, and facilitates implementation of a locally appropriate sequence of interventions in the face of uncertain climate and development futures, and enables necessary transformation (*high confidence*) {CCP2.3; Cross-Chapter Box DEEP in Chapter 17, Cross-Chapter Box SLR in Chapter 3}

A mix of infrastructural, nature-based, institutional and socio-cultural interventions are needed to reduce the multifaceted risk facing C&S, including vulnerability reducing measures, avoidance (i.e., disincentivising developments in high-risk areas), hard- and soft-protection, accommodation, advance (i.e., building up and out to sea) and retreat (i.e., landward movement of people and development) (*very high confidence*) {CCP2.3}. Depending on the C&S archetype, technical limits for hard protection may be reached beyond 2100 under high emission scenarios, with socio-economic and governance barriers reached before then (*medium confidence*). Hard protection can, however, set up lock-in of assets and people to risks and, in some cases, may reach limits, due to technical and financial constraints, by 2100 or sooner depending on the scenario, local SLR effects and community tolerance thresholds (*medium confidence*). Where sufficient space and adequate habitats are available, nature-based solutions can help to reduce coastal hazard risks and provide other benefits, but biophysical limits may be reached before end-century (*medium confidence*). Accommodation is easier, faster and cheaper to implement than hard protection, but limits may be reached by 2100, or sooner in some settings. An adaptation pathways planning approach demonstrates how the solution space can expand or shrink depending on the type and timing of adaptation interventions {CCP1.3.1.2}. As SLR is relentless on human timescales, the solution space will shrink without adoption of an adaptation pathways planning approach (*high confidence*). Due to long implementation lead times and the need to avoid maladaptive lock-in, especially in localities facing rapid SLR and climate-compounded risk, adaptation will be more successful if timely action is taken accounting for long-term (committed) SLR; and if this is underpinned by sustained and ambitious mitigation to slow greenhouse gas emission rates (*high confidence*) {CCP2.3; CCP2.4; Cross-Chapter Box SLR in Chapter 3}.

Individual and collective choices founded on public-centred values and norms, as well as pro-social behaviour, help to foster climate resilient coastal development in C&S (*high confidence*) {CCP2.4.1}.

The effectiveness of different approaches (e.g., awareness and education, market-based and legal strategies) is mediated by how well they address contextual and psycho-social factors influencing adaptation choices in coastal C&S (*medium confidence*). Adaptation options accounting for risk perceptions and aligning with public values are more likely to be socio-culturally acceptable, and consequently facilitate pro-social behavioural change {CCP2.4.1}.

Locally appropriate institutional capabilities, including regulatory provisions and finances dedicated to maintaining healthy coastal social-ecological systems, build adaptive capacity in C&S by the sea (*high confidence*) {CCP2.4}.

Implementing integrated multi-level coastal zone governance, pre-emptive planning, enabling behavioural change, and alignment of financial resources with a wide set of values, will provide C&S with greater flexibility to open up the solution space to adapt to climate change (*high confidence*) {CCP2.4.4}. Insufficient financial resources are a key constraint for coastal adaptation, particularly in the Global South (*high confidence*). Engaging the private sector in coastal adaptation action with a range of financial tools is crucial to address the coastal adaptation funding gap (*high confidence*). Considering the full range of economic and non-economic values will improve adaptation effectiveness and equity across C&S archetypes (*high confidence*). Aligning adaptation in C&S with socio-economic development, infrastructure maintenance, and COVID-19 recovery investments will provide additional co-benefits {CCP2.4.2}. Urgency is also driven by the need to avoid lock-in to new and additional risk, e.g., avoid C&S sprawl into fragile ecosystems and the most exposed coastal localities {CCP2.3}.

Realising global aspirations for climate resilient development depend on the extent to which coastal C&S institutionalise key enabling conditions and chart place-based adaptation pathways to close the coastal adaptation gap, and take urgent action to mitigate greenhouse gas emissions (*medium confidence*) {CCP2.4, Table CCP2.1}.

Since AR5, extensive adaptation planning has been undertaken, but there has not been widespread effective implementation - giving rise to a 'coastal adaptation gap' (*high confidence*). To date, most interventions have been reactive, reliant on protective works alone (*high confidence*). Effectiveness of alternative interventions differs among C&S archetypes, while their feasibility is influenced by geomorphology, socio-economic conditions as well cultural, political and institutional considerations (*very high confidence*). Mismatches between adaptation needs and patterns of physical development are commonplace in many coastal C&S, with especially adverse impacts on poor and marginalised communities in the global North and South (*high confidence*). Overcoming this gap is key to transitioning towards CRD (*medium confidence*). Under higher warming levels and higher SLR, increasingly dichotomous coastal futures will become more entrenched (*medium confidence*), with stark differences between more urbanised, resource-rich coastal C&S dependent on hard protection, and more rural, resource-poor C&S facing displacement and migration {CCP2.3; CCP2.4, Chapter 18}.

Coastal adaptation innovators adopt more flexible, anticipatory and integrative strategies, combining technical and non-technical interventions that account for uncertainties, and facilitate effective resolution of conflicting interests and worldviews (*limited evidence, high agreement*) {CCP2.3; CCP2.4; Chapter 17, 18; Cross-Chapter Box DEEP in Chapter 17}. Moreover, a core set of critical enablers is foundational for C&S to chart CRD pathways. These include building and strengthening governance capabilities to tackle complex problems; taking a long-term perspective in making short-term decisions; enabling more effective coordination across scales, sectors and policy domains; reducing injustice, inequity, and social vulnerability; and unlocking the productive potential of coastal conflict while strengthening local democracy (*medium evidence, high agreement*) {Table CCP2.1, Table CCP2.2}.

C&S play a pivotal role in global aspirations to implement the Paris Agreement, advance the SDGs, and foster CRD. Progress towards these ends depends on the extent to which C&S mobilise urgent and transformational changes to institutionalise enabling conditions; close the coastal adaptation gap by addressing the drivers and root causes of exposure and vulnerability to climate-compounded coastal hazard risks; and drastically reduce greenhouse gas emissions (*medium confidence*) {CCP2.4; Chapter 18}

CCP2.1 Context of Cities and Settlements by the Sea

CCP2.1.1 Introduction and Context

This CCP examines the distinctive roles played by Cities and Settlements (C&S) by the sea in vulnerability and coastal hazard risk reduction, adaptation, resilience, and sustainability in a changing climate. The paper builds upon evidence from AR5 (Wong et al., 2014), the Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) (Magnan et al., 2019; Oppenheimer et al., 2019) and draws material from across WGII AR6 (especially Chapters 3, 6, 9-15). It differs from the sea level rise (SLR) focused analysis of urban areas in SROCC (Section 4.3) through a more integrated assessment that distinguishes between archetypal coastal C&S (CCP2.1.2); sectoral risks to C&S by the sea, (CCP2.2); responses to address these risks (CCP2.3); and enabling conditions and lessons learned (CCP2.4).

We define 'cities and settlements' as concentrated human habitation centres, whether small or large, rural or urban (Chapter 6.1.3). We highlight the unique exposure and vulnerability of coastal C&S resulting from rapid urbanisation at the narrow land-sea interface, concentration of economic activity and at-risk people, many with long-standing cultural ties to the coast and dependence on coastal ecosystems that are prone to climate change impacts (*high confidence*) (He and Silliman, 2019; Lau et al., 2019; Oppenheimer et al., 2019; Sterzel et al., 2020).

Presently, coastal C&S population exposure to ocean-driven impacts from SLR, and other climate-driven impacts is considerable by any measure (Buddemeier et al., 2008; Barragán and de Andrés, 2015; Kay and Alder, 2017; Haasnoot et al., 2019; McMichael et al., 2020; Sterzel et al., 2020). In 2020, almost 11% of global population – 896 million people – resided in C&S within the Low Elevation Coastal Zone (LECZ, coastal areas below 10 m of elevation above sea level that are hydrologically connected to the sea) (Haasnoot et al., 2021b), and potentially increases beyond 1 billion by 2050 (Oppenheimer et al., 2019). Infrastructural and economic assets worth US$6,500-US$11,000 billion are also exposed in the 1-in-100-year floodplain for C&S of all sizes (Neumann et al., 2015; Muis et al., 2016; Brown et al., 2018; Andrew et al., 2019; Kulp and Strauss, 2019; Kirezci et al., 2020; Thomas et al., 2020; Haasnoot et al., 2021b; Hooijer and Vernimmen, 2021).

Further, coastal cities located at higher elevations (e.g., São Paulo, Brazil), or distantly located inland along tidal-influenced rivers (e.g., the Recife Metropolitan Region, Brazil) also have populations and infrastructure exposed to climate impacts. As such, the inclusion of C&S beyond the LECZ is warranted when assessing climate impacts and associated exposure, vulnerabilities and risks. The coastal zone includes some of the world's largest, most densely populated megacities, as well as the fastest-growing urban areas. However, vast coastal areas are sparsely populated, with population in these regions concentrated in smaller C&S, including along subsiding shorelines and in deltas (Nicholls and Small, 2002; McGranahan et al., 2007; Merkens et al., 2018; Edmonds et al., 2020; Nicholls et al., 2021). From this wider perspective, climate change impacts on the coast directly or indirectly affect a large portion of the global population, economic activity and associated critical infrastructure. Some estimates suggest 23-37% of the global population lives within 100 km of the shoreline (Nicholls and Small, 2002; Shi and Singh, 2003; Christopher Small and Joel E. Cohen, 2004; McMichael et al., 2020).

C&S by the sea are thus on the 'frontline' of action to adapt to climate change, mitigate greenhouse gas emissions, and chart climate resilient development (CRD) pathways for several distinct reasons. First, home to a concentrated (and growing) portion of the world's population, many coastal C&S are simultaneously exposed and vulnerable to climate-compounded hazards as well as being centres of creativity and innovation (Glavovic, 2013; Crescenzi and Rodríguez-Pose, 2017; Druzhinin et al., 2021; Mariano et al., 2021; Storbjörk and Hjerpe, 2021). Second, people in C&S by the sea rely on coastal ecosystems, many of which are highly sensitive to climate change impacts that compound non-climate risks and increase the precarity of coastal livelihoods (Lu et al., 2018; He and Silliman, 2019; Thrush et al., 2021). Third, coastal C&S are linked together through a network of ports and harbours that underpin global trade and exchange but are prone to climate change impacts, especially SLR, with significant implications for global CRD prospects (Becker et al., 2018; Christodoulou et al., 2019; Walsh et al., 2019; Hanson and Nicholls, 2020). For these reasons, this paper assesses responses, enabling conditions and lessons learned for addressing climate change in C&S by the sea.

CCP2.1.2 Urbanisation in Coastal Systems: Coastal City and Settlement Archetypes

This assessment uses an archetype framework categorizing coastal C&S according to geomorphological characteristics, urban growth, economic resources, and inequalities (Figure CCP2.1). We use three broadly defined coastal settlement geomorphologies in each row: open coasts (a coast with sediment without river mouths), and two transitional coastal zones with river mouths: estuaries (a wetland receiving sediment from both fluvial and marine sources, which is affected by tide, wave, and river processes), and deltas (a wetland where fluvial sediment is supplied and deposited more rapidly than it can be redistributed by basin processes such as waves and tides) (Bhattacharya, 1978; Barragán and de Andrés, 2015; Kay and Alder, 2017; Haasnoot et al., 2019; Sterzel et al., 2020). Small island C&S are not singled out in this typology because their coastlines often include the geomorphic features listed above, or require a different adaptation approach at larger spatial scales (Haasnoot et al., 2019). Several coastal C&S have a combination of two typologies e.g., Maputo-Matola, Mozambique, and Mumbai, India, having both open and transitional riverine coasts, and can be classed as mixed. We also acknowledge several coastal C&S may have areas sited in mountainous topography that abruptly rise from the coast (e.g., along the Mediterranean), but generally these cities have narrow densely populated coastal shelfs exhibiting these three archetypal categories (Blackburn et al., 2019). Arctic settlements are addressed separately in this CCP.

Coastal C&S within these geomorphological categories are further distinguished according to higher or lower rates of urban growth and inequality – which can be estimated through population growth from national census data, or areal extent of urban development (CEIC); as well as relative urban inequalities estimated by Gini Coefficient data and urban-rural poverty rates (OECD, 2018; OECD, 2020). Combining geomorphological and socio-economic data accounts for urban-rural interconnections and differences; with levels of capital generation, diversity of economic functions and human development indices having previously been used to discern cultural, economic, administrative and political differences between cities and their hinterland (Blackburn et al., 2019; Rocle et al., 2020). For instance, the ecological, cultural and economic footprint of tertiary sectors e.g., coastal tourism associated with the Australian Great Barrier Reef stretches far beyond the nearest onshore settlement of Cairns (Bohnet and Pert, 2010; Brodie and Pearson, 2016).

Some caveats are warranted. First, locating a specific city or settlement in a particular archetype does not account for future reclassification due to growth or shifts in development trajectories. Second, significant socio-economic, political and governance variations exist within many C&S, c.f., impoverished informal settlements alongside wealthy neighbourhoods in cities like Cape Town and São Paulo (also see Table SMCCP2.1). Third, this archetype framework does not explicitly reveal important interconnections between coastal C&S and their hinterlands, or between particular C&S through maritime trade or other economic, socio-cultural and geopolitical inter-dependencies. Notwithstanding these caveats, these archetypes reveal differentiated physical impacts and socio-economic conditions, as well as the variable challenges and opportunities arising for addressing climate change impacts and projected risk, which, depending on coastal type, C&S size, and resource availability, help to inform efforts to adapt and chart CRD for each archetype (Sánchez-Arcilla et al., 2016; Rocle et al., 2020; Sterzel et al., 2020).

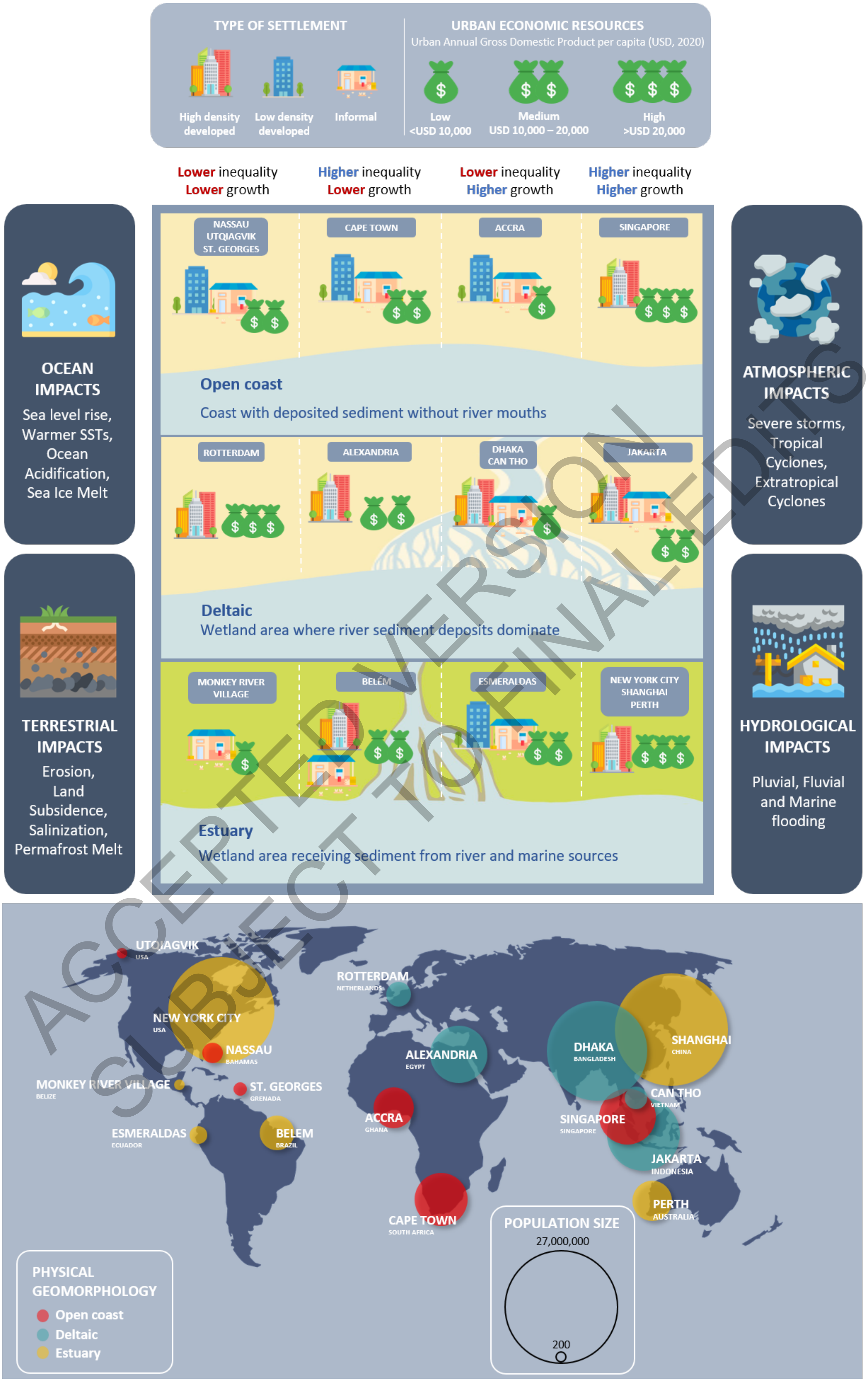
TYPE OF SETTLEMENT
High density developed
Low density developed
Informal
URBAN ECONOMIC RESOURCES
Urban Annual Gross Domestic Product per capita (USD, 2020)
Low <USD 10,000
Medium USD 10,000 – 20,000
High >USD 20,000
Lower inequality Lower growth
Higher inequality Lower growth
Lower inequality Higher growth
Higher inequality Higher growth
OCEAN IMPACTS
Sea level rise, Warmer SSTs, Ocean Acidification, Sea Ice Melt
TERRESTRIAL IMPACTS
Erosion, Land Subsidence, Salinization, Permafrost Melt
ATMOSPHERIC IMPACTS
Severe storms, Tropical Cyclones, Extratropical Cyclones
HYDROLOGICAL IMPACTS
Pluvial, Fluvial and Marine flooding
NASSAU UTQIAGVIK ST. GEORGES
CAPE TOWN
ACCRA
SINGAPORE
Open coast
Coast with deposited sediment without river mouths
ROTTERDAM
ALEXANDRIA
DHAKA CAN THO
JAKARTA
Deltaic
Wetland area where river sediment deposits dominate
MONKEY RIVER VILLAGE
BELEM
ESMERALDAS
NEW YORK CITY SHANGHAI PERTH
Estuary
Wetland area receiving sediment from river and marine sources
UTQIAGVIK USA
NEW YORK CITY USA
NASSAU BAHAMAS
MONKEY RIVER VILLAGE BELIZE
ST. GEORGES GRENADA
ESMERALDAS ECUADOR
BELEM BRAZIL
ROTTERDAM NETHERLANDS
ALEXANDRIA EGYPT
ACCRA GHANA
CAPE TOWN SOUTH AFRICA
DHAKA BANGLADESH
SHANGHAI CHINA
CAN THO VIETNAM
SINGAPORE SINGAPORE
JAKARTA INDONESIA
PERTH AUSTRALIA
PHYSICAL GEOMORPHOLOGY
Open coast
Deltaic
Estuary
POPULATION SIZE
27,000,000
200

Figure CCP2.1: Archetypal C&S affected by ocean, terrestrial, geological, atmospheric and hydrological hazards driven by climate change. Coastal C&S are grouped by physical geomorphology along estuary, deltaic, or open coasts (Barragán and de Andrés, 2015; Kay and Alder, 2017; Haasnoot et al., 2019). C&S are also classified according to relative inequality (e.g., urban Gini coefficient or poverty rates) and growth rates (e.g., recent population growth and increasing density of urban form or built-up area over the past decade) (OECD, 2018; CEIC; OECD, 2020). Settlement types (e.g., informal, low-density or high-density developments) and economic resources (e.g., urban per capita GDP) are also reflected in their respective categories. The bottom map shows the location, 2020 population size, and geomorphological types.

CCP2.2 Climate Change Risks to Cities and Settlements by the Sea

Coastal C&S are at the forefront of climate risk (FAQ CCP2.1). The dynamic interaction between ocean- and climate-drivers and varied coastal geographies influences the character of coastal risks, including many that are unique to C&S by the sea. The interaction of coastal hazards with exposure and vulnerability is differentiated by coastal archetypes, leading to distinct climate change-compounded risks, and associated responses (Figure CCP2.2; Section 1.3.1.2; Simpson et al. (2021)).

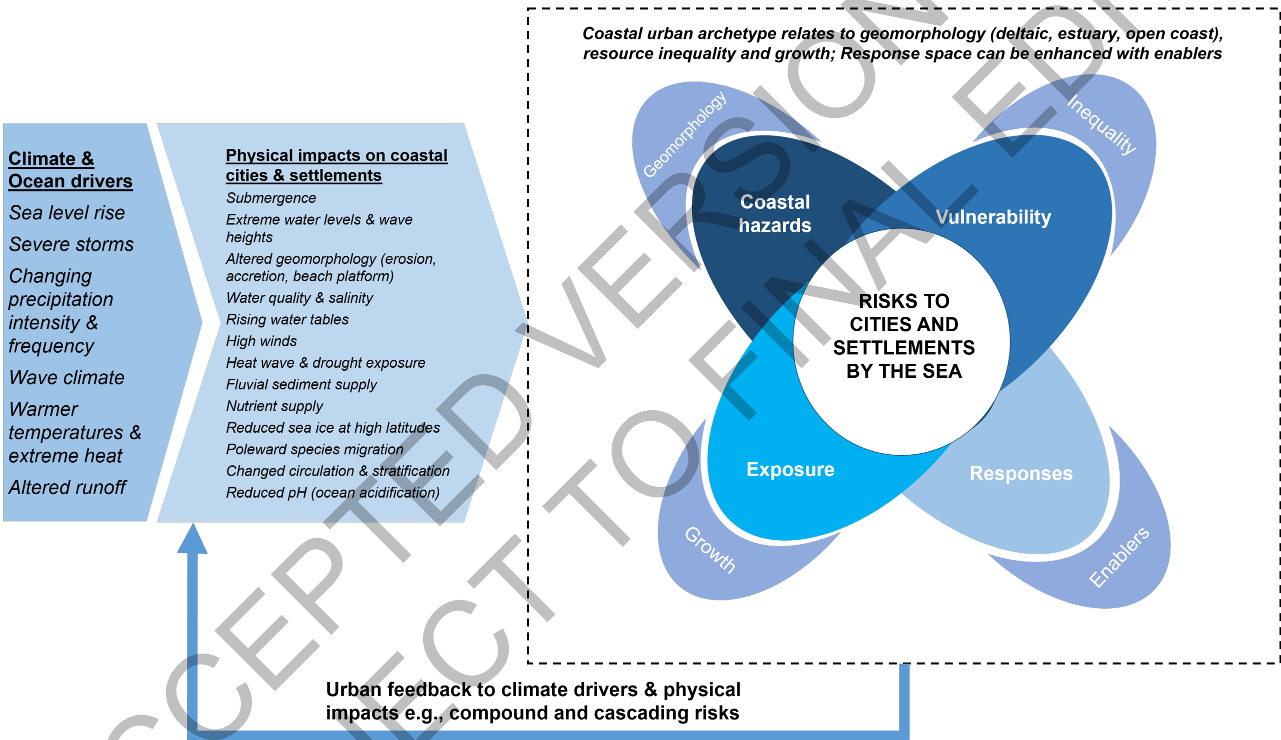

Figure CCP2.2: Schematic of how climate- and ocean-drivers (from WGI Chapter 12.4.10.2) and consequential physical impacts on coastal C&S influence risks assessed in (CCP2.2; Figure based on Simpson et al. (2021) and Section 1.3.1.2). These risks to C&S by the sea are shaped and mediated by adaptation interventions aimed at reducing vulnerability and exposure to coastal hazards given settlement archetypes, as well as by expanding the space for responses to risk via enabling conditions assessed in (CCP2.4). Note that exposure to coastal hazard is controlled chiefly by underlying coastal C&S geomorphology, and changes in coastal hazards and urban growth, including population and infrastructure growth; vulnerability is controlled, for example, by socio-economic development and inequality; and responses that shape risks assessed in (CCP2.3) can be enhanced by enabling conditions, including behavioural change, conducive finance, and prudent governance.

Overall, interactions between climatic and non-climatic drivers of coastal change are increasing the frequency and intensity of many coastal hazards, with settlement archetypes and the wider coastal zone subject to escalating risk (*high confidence*) (Figure CCP2.2; Table SMCCP2.1 for examples of selected coastal C&S). Risks can vary markedly between different archetypes. C&S sited on deltaic and estuarine coasts face additional risks of pluvial flooding compared to open coasts; while greater vulnerabilities arise in coastal settlements with higher inequalities.

Risks to C&S by the sea were extensively covered in SROCC (Oppenheimer et al., 2019) and also in WGII Chapter 3, 6 and regional chapters; in this paper, specific risks to livelihoods, activities, built environment, and ecosystems are assessed in detail in Supplementary Material SMCCP2.1. The ocean- and climate-impact drivers influencing these risks are assessed in WG1 (Section 12.4.10.2), which include extreme heat, pluvial floods from increasing rainfall intensity, coastal erosion and coastal flood driven by increasing SLR, and tropical cyclone storm surges (*high confidence*). Further, Arctic coastal settlements are particularly exposed to climate change due to sea ice retreat as well as from permafrost melt (*high confidence*).

Without adaptation, risks to land and people in coastal C&S from pluvial- and coastal-flooding will *very likely*[2] increase substantially by 2100 and *likely* beyond as a result of SLR, with significant impacts even under RCP2.6 (Neumann et al., 2015; Muis et al., 2016; Brown et al., 2018; Nicholls et al., 2018; Kulp and Strauss, 2019; Oppenheimer et al., 2019; Kirezci et al., 2020; Haasnoot et al., 2021b). Across these studies, by 2100, 158-510 million people and US$7,919-US$12,739 billion assets under RCP4.5, and 176-880 million people and US$8,813-US$14,178 billion assets under RCP8.5, will be within the 1-in-100-year floodplain (*very high confidence*). There is *medium confidence* that accelerated SLR will increase shoreline erosion globally, although biophysical feedbacks will allow many coastlines to maintain relatively stable morphology if room exists to accommodate mangroves in estuarine and deltaic coasts, and beach movement along open coasts (Kench et al., 2015; McLean and Kench, 2015; Perkins et al., 2015; Richards and Friess, 2016; CCC, 2017; Duncan et al., 2018; Luijendijk et al., 2018; Mentaschi et al., 2018; Schuerch et al., 2018; Ghosh et al., 2019; Masselink et al., 2020; Toimil et al., 2020; Vousdoukas et al., 2020b). Limiting emissions to RCP2.6 (corresponding to a mean post-industrial global temperature increase of 1.5-2C) significantly reduces future SLR risks (Hinkel et al., 2014; Brown et al., 2018; Nicholls et al., 2018; Schinko et al., 2020). For example, by 2100 the population at risk of permanent submergence increases by 26% under RCP2.6 compared with 53% under RCP8.5 (median values from Kulp and Strauss (2019).

There is *high confidence* about regionally differentiated but considerable global sectoral impacts in coastal C&S arising from exposure to hazards. Tangible impacts include damage, loss of life, loss of livelihoods, especially fisheries and tourism (Tessler et al., 2015; Avelino et al., 2018; Hoegh-Guldberg et al., 2018; Seekamp et al., 2019; Arabadzhyan et al., 2020); negative impacts on health and wellbeing, especially under extreme events (McIver et al., 2016; Bakkensen and Mendelsohn, 2019; Bindoff et al., 2019; Pugatch, 2019); and involuntary displacement and migration (Hauer, 2017; Davis et al., 2018; Neef et al., 2018; Boas et al., 2019; McLeman et al., 2021). Intangible impacts include psychological impacts due to extreme events, such as heat-waves, flooding, droughts, and tropical cyclones; heightened inequality in coastal archetypes with systematic gender/ethnicity/structural vulnerabilities; and loss of things of personal or cultural value, and sense of place or connection, including existential risk of the demise of nations due to submergence (Allison and Bassett, 2015; Barnett, 2017; Schmutter et al., 2017; Weir et al., 2017; Farbotko et al., 2020; Hauer et al., 2020; Hoffmann et al., 2020; Bell et al., 2021). Impacts extend beyond the coastal zone, for example disruption to ports and supply chains, with major geopolitical and economic ramifications from the C&S to global scale (*very high confidence*) (Becker et al., 2018; Camus et al., 2019; Christodoulou et al., 2019; Walsh et al., 2019; Hanson and Nicholls, 2020; Yang and Ge, 2020; Izaguirre et al., 2021; León-Mateos et al., 2021; Ribeiro et al., 2021).

Many coastal C&S have densely built physical infrastructure and assets that are exposed and vulnerable to climate change-compounded coastal hazards. There is *high confidence* that SLR, land subsidence, poorly regulated coastal development, and the rise of asset values are major drivers of future risk in all coastal archetypes and, without adaptation, built environment risks, especially in archetypes with high exposure due to rapid growth, are expected to rise considerably in this century across all RCPs (Koks et al., 2019; Magnan et al., 2019; Oppenheimer et al., 2019; Abadie et al., 2020; Nicholls et al., 2021). Archetypes with more

[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.

informal settlements are often disproportionally exposed to coastal risks (Roy et al., 2016; Hallegatte et al., 2017; Bangalore et al., 2019).

There is *high confidence* that loss of coastal ecosystem services will increase risks to all coastal C&S archetypes that include reduced provisioning of materials and food (e.g., wood, fishery habitat) (Kok et al., 2021), amelioration of coastal hazards (e.g., attenuation of storm surges, waves, and containing erosion) (Section 2.3.2.3; Godfroy et al., 2019; Schoutens et al., 2019; Zhu et al., 2020b), climate change mitigation (through carbon sequestration) (Macreadie et al., 2017; Rovai et al., 2018; Ward, 2020), water quality regulation (nutrient, pollutant and sediment retention and cycling) (Wilson et al., 2018; Zhao et al., 2018), and recreation and tourism (Pueyo-Ros et al., 2018).

Most studies of coastal C&S focus on adaptation to a single or limited set of risks, but there is *high confidence* that compound and cascading risks significantly alter C&S risk profiles (Nicholls et al., 2015; Estrada et al., 2017; Edmonds et al., 2020; Eilander et al., 2020; Yin et al., 2020; Ghanbari et al., 2021). Extreme events can lead to cascading infrastructure failures that cause damage and economic losses well beyond the coastal zone (Haraguchi and Kim, 2016; Kishore et al., 2018; Rey et al., 2019; So et al., 2019), and have forced evacuation of C&S and small islands (Look et al., 2019; Thomas and Benjamin, 2020). These risks are exacerbated by non-climate drivers, e.g., compound and cascading impacts arising from exposure to tropical cyclones and COVID-19 that threaten population health and hamper pandemic responses (Salas et al., 2020; Shultz et al., 2020a; Shultz et al., 2020b). There is emerging evidence (*low confidence*) from individual coastal C&S, and regional case studies (e.g., in Europe, Australia, and the U.S.), illustrating the increasing influence of compound risks on vulnerability due to accelerating climate change (Wahl et al., 2015; Xu et al., 2019; Kirezci et al., 2020).

Figure CCP2.3 shows that ocean-driven coastal risks to people, land, and infrastructure in East and Southeast Asia are highest compared to other regions, even for low levels of projected SLR. However, risks facing coastal C&S are high across the globe, especially under higher SLR projections (*high confidence*). Without adaptation, the population at-risk to a 100-year coastal flood increases by ~20% if current global mean sea level rises by 0.15m relative to current levels; this at-risk population doubles at 0.75m rise in mean sea level, and triples at 1.4m. Simultaneously, coastal C&S are projected to experience shoreline retreat, with coastlines having more than 100 m retreat increasing ~165% if current mean sea levels rise between 0.23-0.53 m. Ocean-driven flooding in coastal C&S is also projected to disrupt flights by up to three orders of magnitude per year in selected coastal C&S as mean sea level increases. Typically, larger risks correspond with archetypes associated with higher inequality and high growth rates, especially in deltas, leading to larger vulnerability and exposure respectively under higher warming levels.

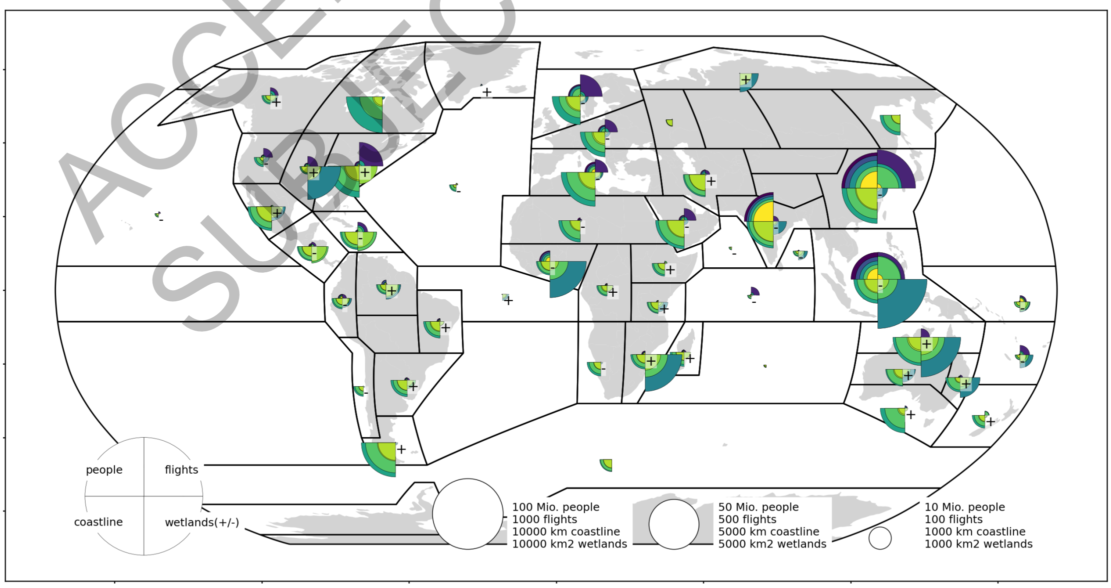

Figure CCP2.3: Map of coastal C&S risks according to IPCC regions, showing risks to people from a 100-year coastal flood event (*100.000) (Haasnoot et al., 2021b), risks to loss of coastal land (length of coast with more than 100 m retreat) (Vousdoukas et al., 2020b), risks to the built environment (airports at risk indicated by number of flights disrupted (Yesudian and Dawson, 2021)) and risk to wetlands (± indicates positive or negative area change) (Schuerch et al., 2018). Risks are reported against global mean sea level rise relative to 2020, depending on data availability.

CCP2.3 Adaptation in Cities and Settlements by the Sea

CCP2.3.1 Introduction

This section extends SROCC Chapter 4 (Oppenheimer et al., 2019), which focused on SLR, and draws from Chapters 6 and 9-15 to cover all C&S archetypes. Adaptation interventions span psycho-social (e.g., awareness raising), economic (e.g., insurance), physical (e.g., retreat), technical (e.g., sea walls) and natural dimensions (e.g., wetland restoration) (Nicholls et al., 2015). Adaptation strategies for coastal C&S are typically classified in terms of protect, accommodate, advance, and retreat, which are used below.

Some coastal cities have adapted to meters of SLR in the past, indicating that adaptation is feasible (Esteban et al., 2020a), but future adaptation options are influenced by variations in projected socio-economic conditions and rates of SLR (Cross-Chapter Box SLR in Chapter 3). To date, interventions are typically implemented reactively in response to extreme events (*high confidence*); but leading adaptors are increasingly proactive (*medium confidence*) (Araos et al., 2016; Dulal, 2019; Dedekorkut-Howes et al., 2020), and those that move from previously rigid to more adaptive and flexible solutions, using an adaptation pathways approach that keeps options open in the face of uncertainty, have improved climate risk management (*high confidence*) (Sections 9.9.4; 10.5; 11.7; 12.5.5; 13.2; 14.7; 15.5; Cross-Chapter Box DEEP in Chapter 17; Walker et al., 2013; Marchau et al., 2019).

The effectiveness of different strategies and interventions is mediated by physical coastal features for hard adaptation measures, and by the scope and depth of soft adaptation measures, e.g., the coverage extent of social safety nets for urban poor (Section 6.3). Their feasibility is also shaped by socio-economic, cultural, political and institutional factors, e.g., social acceptance of measures (CCP2.2, SMCCP2.2.4). Together, response effectiveness and feasibility shape the solution space for mediating risks (Section 1.3.1.2; Figure CCP2.3; Simpson et al., 2021;), which is achieved chiefly through governance interventions e.g., laws and regulations (Haasnoot et al., 2020). Access to financial resources expands the solution space, most notably for some resource-rich coastal archetypes (CCP2.4.2; Table SMCCP2.1; Sections 3.6, 14.7), but rapid population growth and unfolding climate-driven impacts can increase risks (Haasnoot et al., 2021a) especially for small island and poorer C&S (*high confidence*) (Section 15.3; Magnan and Duvat (2020).

CCP2.3.2 Protection of Coastal Cities and Settlements

CCP2.3.2.1 Hard Engineering Measures

Hard engineering protection measures are commonly used to reduce coastal flooding, and to drain or store excess water from intense precipitation. Many coastal cities, in particular densely populated and high resource archetypes, have planned and are planning to continue a protection-based strategy, comprising e.g., breakwaters, sea walls and/or dikes, which could be raised or complemented with large barriers or with ‘super-levees’ enabling construction on top of them (*high confidence*) (Table SMCCP2.1; Takagi et al., 2016; Haasnoot et al., 2019; Hall et al., 2019; Esteban et al., 2020b)).

Protection is effective in the short- to medium-term for many coastal cities, and can be cost-effective in the 21st Century (section CCP2.4.2), but residual risk remains because protection can fail. Even under RCP8.5, technical limits to hard protection may only be reached after 2100 in many regions, but socio-economic and institutional barriers may be reached before then (Hinkel et al., 2018). With progressive SLR, protection eventually becomes unaffordable and impractical (Strauss et al., 2021). Combining hard engineering measures with nature-based solutions, spatial planning and early warning systems, can help to contain residual risk (Du et al., 2020). Protective works do not prevent salinisation and higher groundwater levels (Alves et al., 2020), and can lead to loss of coastal habitat (Cross-Chapter Box SLR in Chapter 3; Achete et al. (2017); Cooper et al. (2020)). Hard protection measures also create long-term path-dependency as they last for decades and attract new development, locking in impact and exposure as C&S grow, with the expectation of ongoing protection (Chapter 3; Di Baldassarre et al., 2015; Gibbs, 2016; Griggs and Patsch, 2019; Siders, 2019a).

CCP2.3.2.2 Soft Engineering and Sediment-based Measures

Sediment-based interventions e.g., beach nourishment, aim to limit coastal erosion and flood risk and have become a widely applied strategy especially in open coast archetypal C&S; in part because there is less impact on adjacent beaches and coastal ecology, and lower construction and maintenance costs compared to hard protection (*high confidence*) (Parkinson and Ogurcak, 2018). In addition, it is considered a flexible strategy under more rapid SLR conditions (Kabat et al., 2009; Stive et al., 2013), and can be applied in the form of a mega-nourishment strategy wherein natural currents distribute sand along the coast (Stive et al., 2013; de Schipper et al., 2021). However, there are limits to this strategy due to environmental impacts, costs, and the availability of potential and permitted sand reserves which may be unable to keep up with higher rates of SLR (Parkinson and Ogurcak, 2018; Haasnoot et al., 2019; Harris et al., 2021; Staudt et al., 2021). Simultaneously, other socio-economic needs (e.g., damming rivers, or for building and transport infrastructure) may compete for sand as a limited resource (Torres et al., 2017; Bendixen et al., 2019). Regional and global governance provisions (e.g., spatial reservations for sand mining; international frameworks for distribution) could improve long-term feasibility (Torres et al., 2017; Parkinson and Ogurcak, 2018; Bendixen et al., 2019; Haasnoot et al., 2019).

CCP2.3.2.3 Nature-based Measures

Nature-based measures, such as retaining mangroves and marshes, have been successful in reducing deaths and damage due to storm surges (*high agreement, medium evidence*) (Das and Vincent, 2009; Saleh and Weinstein, 2016; Narayan et al., 2017; Triyanti et al., 2017; Hochard et al., 2019; del Valle et al., 2020), and across the USA reportedly provide USD23.2 billion yr-1 in storm protection services (Saleh and Weinstein, 2016). They are also a cost-effective strategy (*medium confidence*) that provide C&S with additional co-benefits through ecosystem services (*high confidence*) (Cross-Chapter Box NATURAL in Chapter 2; Section 2.2.4; Narayan et al., 2016; Depietri and McPhearson, 2017; Morris et al., 2018; Reguero et al., 2018; Chausson et al., 2020; Du et al., 2020; NIES and ISME, 2020; Reguero et al., 2020; Sudmeier-Rieux et al., 2021).

Nature-based measures can reduce inland propagation of extreme sea levels (high tides, storm surges) (*high agreement*) (Godfroy et al., 2019; James et al., 2020; Zhu et al., 2020b), with vertical reduction in water levels ranging from 5-50cm/km behind large mangroves and marshes (Stark et al., 2015; Van Coppenolle and Temmerman, 2020). They also attenuate wind-driven waves and reduce shoreline erosion (*high agreement*), and this can be as much as 90% over stretches of 10-100 meters for dense mangrove and marsh vegetation (*medium evidence*) (Li et al., 2014; Möller et al., 2014; Vuik et al., 2016; Vuik et al., 2018; Godfroy et al., 2019; Zhu et al., 2020a) and up to 40% for dunes (Feagin et al., 2019). Coral reefs on average reduce wave energy by 97% (Ferrario et al., 2014). Seagrass meadows attenuate wind waves to a lesser extent, and are only effective in water <0.2 m deep (Ondiviela et al., 2014; Narayan et al., 2016; Morris et al., 2019).

Within limits, coastal ecosystems can respond to rising sea-level through sediment accretion and lateral inland movement (Kirwan et al., 2016; Schuerch et al., 2018). Nature-based measures have greatest potential in coastal deltas and estuaries, where human populations are exposed but large ecosystems, like mangroves and marshes, can be conserved and restored (Menéndez et al., 2020; Van Coppenolle and Temmerman, 2020). Their feasibility depends on physical, ecological, institutional, and socio-economic conditions that are typically locality-dependent (Temmerman and Kirwan, 2015; Arkema et al., 2017); space may not be available in certain places (e.g., intensive urbanization on the shoreline), or these measures may conflict with other human demands for scarce land (Tian et al., 2016). Successful nature-based measures require site-specific knowledge and science-based design, pilot monitoring, and adaptive upscaling (Evans et al., 2017; Nesshöver et al., 2017), and more rigorous understanding of long-term performance, maintenance and costs (Kumar et al., 2021).

Nature-based measures are increasingly implemented in combination with hard protection measures (Hu et al., 2019; Schoonees et al., 2019; Morris et al., 2020; Oanh et al., 2020). They can reduce dike failure and increase design life where sediment accretion allows wetlands to respond to SLR (Jongman, 2018; Vuik et al., 2019; Zhu et al., 2020a). There is *high agreement* that a hybrid strategy combining hard and soft protect strategies is more effective and less costly under many circumstances; and there is *limited evidence* that technical limits will be encountered with such a strategy for low-lying C&S built on soft or permeable soil or with high exposure to monsoons and river discharges (Spalding et al., 2014; Sutton-Grier et al., 2015; Pontee et al., 2016; Morris et al., 2018; Reguero et al., 2018; Du et al., 2020; Morris et al., 2020; Seddon et al., 2020; Waryszak et al., 2021).

CCP2.3.3 Accommodation of the Built Environment

The most effective solution for limiting the growth of climate risks in C&S by the sea is to avoid new development in coastal locations prone to major flooding and/or SLR impacts (*very high confidence*) (Cross-Chapter Box SLR in Chapter 3; Oppenheimer et al., 2019; Doberstein et al., 2019). For existing C&S accommodation includes biophysical and institutional responses to reduce exposure and/or vulnerability of coastal residents, human activities, ecosystems and the built environment, enabling continued habitation of coastal C&S (Oppenheimer et al., 2019). Next to hard protection, accommodation is the most widely used adaptation strategy across all archetypes to date (*high confidence*) (Sayers et al., 2015; Olazabal et al., 2019; Le, 2020). Measures include elevation or flood-proofing of houses and other infrastructure (Garschagen, 2015; Aerts et al., 2018; Buchori et al., 2018; Jamero et al., 2018; Tamura et al., 2019), spatial planning (e.g. Duy et al. (2018)), amphibious building designs (Nilubon et al., 2016), increasing water storage and/or drainage capacity within C&S (Chan et al., 2018), early warning systems and disaster responses (Hissel et al., 2014), and slum upgrading (Jain et al., 2017; Olthuis et al., 2020).

Raising land, or individual buildings, can avert flooding and can be done artificially or as nature-based interventions through river diversion and control in estuarine and deltaic archetypes (Nittrouer et al., 2012; Auerbach et al., 2015; Day et al., 2016; Sánchez-Arcilla et al., 2016; Hiatt et al., 2019; Cornwall, 2021). Nature-based land elevation is limited by sediment supply and can address SLR rates of up to 10mm/yr (Kleinhans et al., 2010; Kirwan et al., 2016; IPCC, 2019). It also assumes that existing land-use patterns permit land raising (e.g., in rural or newly developed areas (Scussolini et al., 2017). Artificial land raising can achieve significant elevations and be implemented over a large spatial scale (Esteban et al., 2015; Esteban et al., 2019). Raising land can be cost beneficial for small areas, or where lower safety levels are satisfactory, but protection is usually more economical for larger areas, though both strategies are often combined (Lendering et al., 2020).

Accommodation measures can be very effective for current conditions and small changes in SLR (Laurice Jamero et al., 2017; Scussolini et al., 2017; Oppenheimer et al., 2019; Du et al., 2020; Haasnoot et al., 2021a), and buy time to prepare for more significant changes in sea level and other climate compounded coastal hazards. However, limits to this strategy occur comparatively soon in some locations, possibly requiring protection in the medium-term, and retreat in the long run and beyond 2100, particularly in scenarios of dramatic SLR (Oppenheimer et al., 2019). For the foreseeable future, accommodation can play an important role in combination with protective measures, to form hybrid interventions, with higher effectiveness than either approach in isolation (Du et al., 2020). Accommodation can play an increasingly important role where hard protection is neither technically nor financially viable; but detailed studies about expected trends of accommodation are lacking (Oppenheimer et al., 2019).

CCP2.3.4 Advance

An advance strategy creates new land by building seaward, which can reduce risk for the hinterland and the newly elevated land, either by land reclamation through land-filling or polderisation through planting of vegetation to support natural land accretion (Wang et al., 2014; Sengupta et al., 2018). Advance has occurred in all archetypes (*high confidence*); from open coasts (e.g., Singapore) and small atolls (e.g., Hulhumalé in the Maldives) (Hinkel et al., 2018; Brown et al., 2020) to cities on estuaries (e.g., Rotterdam) and deltas (e.g., Shanghai Sengupta et al. (2020)), and mountainous coasts (e.g., Hong Kong SAR, China). Earth observations show between 14,000-33,700 km^2 of land has been gained in coastal areas over the past 30 years, the dominant drivers being urban development and activities like fish farming (Donchyts et al., 2016; Zhang et al., 2017; Mentaschi et al., 2018). Advancing seawards through large floating structures may be a viable option in future (Wang et al., 2019; Setiadi et al., 2020; Wang and Wang, 2020), but is at an experimental stage, and, so far, only applied in calm water within a city as part of an accommodate strategy (Scussolini et al., 2017; Penning-Rowsell, 2020; Storbjörk and Hjerpe, 2021).

Advance is seen as an attractive option to adapt to SLR in growing cities that are already densely populated and have limited available land for safe development, with a moderate to high adaptive capacity. But advance can have significant negative impacts on coastal ecosystems and livelihoods, requires substantial financial and material resources and time to build, and may be subject to land subsidence (Jeuken et al., 2014; Garschagen et al., 2018; Brown et al., 2019; NYCEDC, 2019; Oppenheimer et al., 2019; Sengupta et al., 2020; Bendixen et al., 2021).

CCP2.3.5 Retreat

Retreat is a strategy to reduce exposure and eventually risks facing coastal C&S by moving people, assets and activities out of coastal hazard zones (Oppenheimer et al., 2019). This includes adaptive migration, involuntary displacement, and planned relocation of population and assets from the coast (Section 7.2.6; Cross-Chapter Box CB-MIGRATE in Chapter 7).

Planned relocation in coastal C&S with high hazard exposure and climate impacts is already occurring and has been increasing in frequency (*medium confidence*) (Hino et al., 2017; Mortreux et al., 2018), with some small islands purchasing land in other countries to facilitate movement (Klepp, 2018). In the Arctic, the pressure to relocate away from the coast is expected to rise given the interacting effects of permafrost thaw and coastal erosion. Native villages in Alaska are already relocating (Ristroph, 2017; Ristroph, 2019). Involuntary resettlement may be a secondary effect of large-scale hard coastal protection projects, or inner-city river and canal regulation. In Jakarta, for example, a new giant seawall project involves resettling coastal households along large parts of the coastline (Garschagen et al., 2018).

Increased migration is to be expected across different climate scenarios, but there is *limited evidence* and *medium agreement* about the scale of climate-induced migration at the coast (Oppenheimer et al., 2019) (Chapter 16, RKR on peace). Planned relocation is expected to rise in C&S in response to SLR and other coastal hazards (*high agreement, medium evidence*) (Siders et al., 2019). Relocation has predominantly been reactive to date, but increased attention is being given to pre-emptive resettlement and the potential pathways and necessary governance, finance and institutional arrangements to support this strategy (Ramm et al., 2018; Lawrence et al., 2020; Haasnoot et al., 2021a). There is *limited evidence* about the costs of planned relocation and retreat more generally (Oppenheimer et al., 2019).

Retreat can effectively reduce the exposure of urban residents to coastal hazards and provide opportunity for re-establishment of ecosystems services (*very high confidence*) (Song et al., 2018; Carey, 2020; Hindsley and Yoskowitz, 2020; Lincke et al., 2020; Lincke and Hinkel, 2021). But there is *high confidence* that it can sever cultural ties to the coast (Reimann et al., 2018) and can lead to negative and inequitable socio-economic effects for resettled communities if not planned and implemented in ways that are inclusive, just and address cultural, place-attachment and livelihood considerations (Ajibade, 2019; Adger et al., 2020; Carey, 2020; Jain et al., 2021; Johnson et al., 2021), and the rights and practices of Indigenous People (Nakashima et al., 2018; Ristroph, 2019; Mohamed Shaffril et al., 2020). If planned well ahead and aligned with social goals, pathways to managed retreat can achieve positive outcomes and provide opportunities for transformation of coastal C&S (Haasnoot et al., 2021a; Mach and Siders, 2021). There is *medium confidence* that the availability of suitable and affordable land, and appropriate financing, is a major bottleneck for planned relocation (Alexander et al., 2012; Ong et al., 2016; Hino et al., 2017; Fisher and Goodliffe, 2019; Hanna et al., 2019; Buser, 2020; Doberstein et al., 2020), particularly in very dense mega-urban areas (Ajibade, 2019) and crowded small islands (Neise and Revilla Diez, 2019; Weber et al., 2019; Kool et al., 2020; Lincke et al., 2020)

CCP2.3.6 Adaptation Pathways

No single adaptation intervention comprehensively addresses coastal risks and enables CRD. An adaptation pathways approach can facilitate long-term thinking, foresee maladaptive consequences and lock-ins, and address dynamic risk in the face of relentless and potentially high SLR; and frame adaptation as a series of manageable steps over time (Cross-Chapter Box DEEP in Chapter 17; Figure CCP2.4; Haasnoot et al.

(2019)). A portfolio of hard, soft and nature-based interventions can be used to implement strategies to protect, accommodate, retreat, and advance, individually or in combination.

The strategy, and portfolio of interventions, can be adjusted in response to new information about SLR and other climate risks according to economic, environmental, social, institutional, technical or other objectives. In cases of rapid SLR, it may be necessary to implement a short-term protection strategy to buy time to implement more transformative and enduring strategies (*high confidence*) (Du et al., 2020; Lawrence et al., 2020; Morris et al., 2020; Haasnoot et al., 2021a). There is *high agreement* that combining and sequencing adaptation interventions can reduce risk over time (Du et al., 2020; Morris et al., 2020). Phasing interventions can help to spread costs and minimise regret (de Ruig et al., 2019), provided that options are kept open to adjust to changing conditions (Buurman and Babovic, 2016; Haasnoot et al., 2019; Hall et al., 2019).

Many megacities plan to continue a protection strategy (Table SMCCP2.1). This becomes increasingly costly, institutionally challenging, and requires space possibly facilitated through local relocation. There is *high agreement* that many C&S are locked-in to a self-reinforcing pathway: coastal defences have a long lifetime and attract people and assets that require further protection (Gralepois et al., 2016; Bubeck et al., 2017; Welch et al., 2017; Di Baldassarre et al., 2018; Jongman, 2018). Transitioning to alternative pathways may involve major transfer and sunk costs (e.g., Gralepois et al. (2016)), but these may prove to be less costly in the long-term. Because of considerable inertia in the built form of cities, such transitions are more likely to be successful and aligned with societal goals if embedded early into C&S planning and development processes that enable transformational change and CRD (Sections 6.4.8; 11.7; 13.11; Box 18.1; Ürge-Vorsatz et al., 2018; Siders 2019b).

In islands, hybrid options of nature-based (where space and environmental conditions allow) and protect measures (on wealthy, already densely populated islands) could reduce risk for low SLR in the next few decades (Section 15.5). Where feasible, retreat is a compelling option to reduce risk (Figure CCP2.4). With higher rates and levels of SLR in the medium- to long-term, financial, governance and material barriers may differentiate resource-rich islands and more rural islands, leading to a dichotomy between which islands retreat or can rely on protection for a period of time.

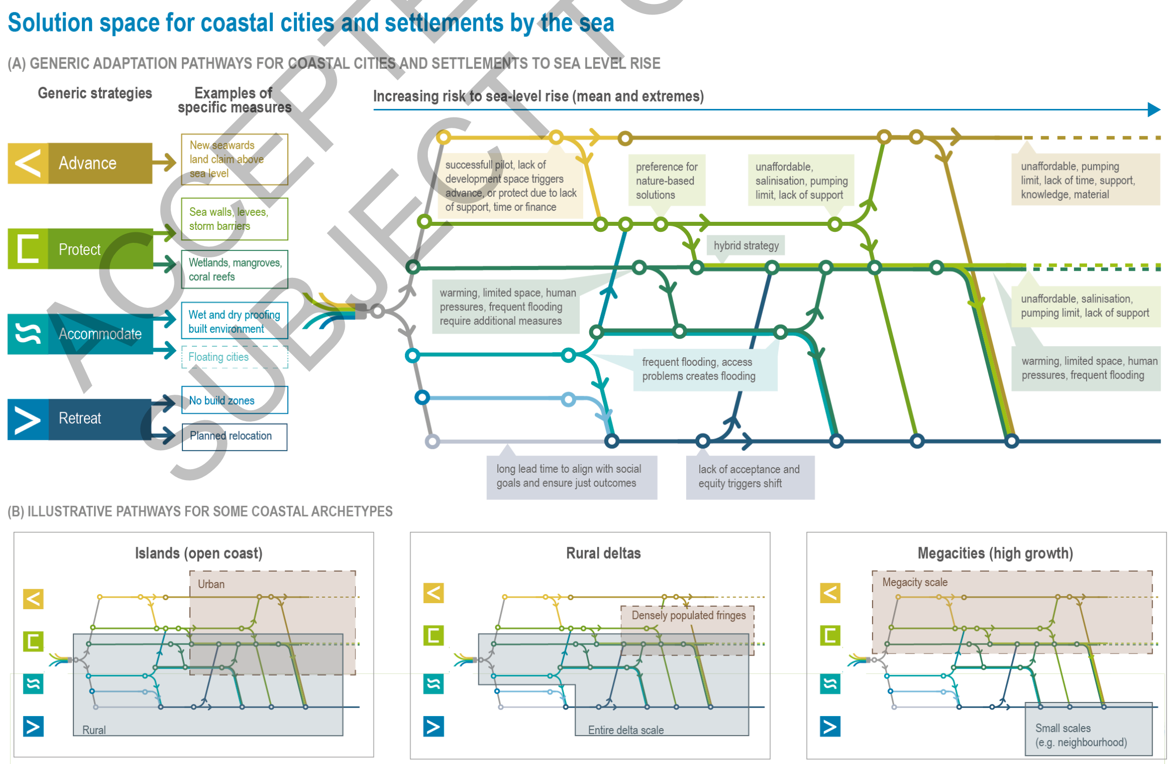

Figure CCP2.4: Generic adaptation pathways for coastal C&S (a) and the typical solution space with illustrative pathways for three coastal archetypes (b). As risk increases under rising sea levels, solutions need to be combined or sequenced in order contain risk. Pathways involve different trade-offs. Based on Table SMCCP2.1 - 2.3; Chapters 11 and 13, Magnan and Duvat (2020); Lawrence et al. (2020); Haasnoot et al. (2019). Depending on local conditions, archetype and risk tolerance, alternative pathways are needed and possible to contain risk. Dashed lines indicate uncertainty in pathway (a). Dashed and plain borders are used for illustrating various local situations within each archetype (b).

CCP2.4 Enabling Conditions and Lessons Learned

Here we distil enabling conditions and lessons learned from C&S archetypes adapting to coastal risk (Table SMCCP2.1; Table SMCCP2.2; Sections 6.4; 9.9.4; 10.5; 10.6; 11.7; 11.8; 12.5.5; 13.6.2; 14.7.2; 15.6).

CCP2.4.1 Enabling Behavioural Change

Changing behaviours and practices are a critical enabler of adaptation in coastal C&S. Behavioural enablers include using economic, informational, socio-cultural, and psychological incentives to motivate adaptation actions (van Valkengoed and Steg, 2019; Gibbs, 2020): e.g., leveraging Indigenous Knowledge and Local Knowledge (IKLK) and religious beliefs to incentivise adaptation (Hiwasaki et al., 2014; Ford et al., 2015); implementing subsidies/bans to incentivise sustainable aquaculture (Condie et al., 2014; Krause et al., 2020); providing localized flood warnings and forecasts to inform individual risk perceptions and risk management (Bruine de Bruin et al., 2014; Gibbs, 2020), or incentivise risk insurance (Bradt, 2019).

There is *high evidence* with *medium agreement* that public attitudes and perceptions of climate risks significantly influence individual adaptation behaviour across all coastal archetypes (Bradt, 2019; Buchanan et al., 2019; Javeline et al., 2019). Information on climate risks and impacts (e.g., flood warnings, SLR projections) strongly shapes public perceptions of climate risks. It is most effective at incentivising and enabling adaptation behaviour if provided at meaningful spatial and temporal scales, with guidance about how to interpret the information (*medium evidence, high agreement*) (Gibbs (2020); Cools et al. (2016)). Further, there is *medium evidence, high agreement* that integrating climate information with existing knowledge systems, such as local norms and beliefs and IKLK, is critical to improve public acceptability and develop context-specific solutions (Ford et al., 2015).

A second key enabler of coastal adaptation behaviour is self-efficacy or belief in one's capacity to undertake adaptation. There is *medium evidence, high agreement* that high risk perception is in itself insufficient to motivate people to undertake adaptation (Fox-Rogers et al., 2016; Roder et al., 2019; Gibbs, 2020) and needs to be supplemented with supportive policy and financial provisions to enable adaptation Fox-Rogers et al. (2016).

Third, there is *medium evidence* on how trust in state-led, planned adaptation measures can hinder or enable individual adaptation (van Valkengoed and Steg, 2019; Schneider et al., 2020). As an enabler, trust in early warnings can mitigate flood risk by incentivising evacuation (Binh et al., 2020) and high trust can help overcome uncertainty attached to projected climate impacts and/or adaptation decisions (Frederiksen, 2014). As a barrier, low trust can disincentivise adaptation, e.g., willingness to pay for flood insurance (Roder et al., 2019) or public support for managed retreat (Hanna et al., 2020). Paradoxically, high trust in existing adaptation measures can reduce people's perceived need for ongoing adaptation (e.g., levees potentially reducing individual flood-proofing actions). Adaptation decisions also manifest 'single-action bias' with modest-cost adaptation actions in the present disincentivising further adaptation (Buchanan et al., 2019).

Several tools to incentivise adaptation behaviour are being tested around the world – e.g., nudges and boosts[2] are being experimented with to shape individual risk beliefs and demand for flood insurance (Bradt, 2019); ordinances are being used to ban, authorise or limit certain activities (Herrick, 2018); subsidies and financial support being used to incentivise adaptation such as subsidised beach nourishment (McNamara et al., 2015); and zoning restrictions and building codes restrict or guide climate-resilient infrastructural development Schneider et al. (2020). Overall, the literature affirms that behavioural interventions are more readily taken up if they are: aligned with cultural practices, norms, and beliefs; on temporal scales within peoples' planning horizons; and build upon relationships of trust and legitimacy (Donner and Webber, 2014; Herrick, 2018; Schneider et al., 2020).

CCP2.4.2 Finance

Lack of financial resources is a key constraint affecting all coastal archetypes (*high confidence*) (Table SMCCP2.2). Adaptation to coastal hazards is costly – the global costs of protecting coastal areas with levees (annual investment and maintenance costs) are estimated at US$12–71 billion in 2100 with SLR up to 1.2m (Hinkel et al., 2014). Broadly speaking, it is cost-effective to contain coastal hazard risk in the short- to medium-term in densely populated wealthy localities by using protective works but such measures are unaffordable in dispersed poorer coastal C&S (Lincke and Hinkel, 2018).

Archetypes with high adaptive capacity may currently have financial resources to meet adaptation needs, but such funding may be unsustainable in the long-term. In Catalonia, while public funds are currently used to finance beach nourishment, these costs will increase with SLR and it is unclear if public finance will remain a feasible source (Hinkel et al., 2018). Even in relatively richer municipalities, financing adaptation is constrained by other urban priorities (Bisaro and Hinkel, 2018). In Europe, shifting responsibilities from national governments to transnational and local actors has resulted in reduced national budgets for coastal adaptation investment and increased pressure on local authorities to raise public funds for adaptation without alienating electoral bases (Bisaro and Hinkel, 2018).

Locations in the Global South have limited public budgets allocated to coastal adaptation and may rely on international donor aid (Donner et al., 2016; Araos et al., 2017). Such aid is often inconsistent and short-term, which limits long-term maintenance of knowledge, equipment and infrastructure needed to sustain adaptation measures beyond initial funding periods (Weiler et al., 2018; Thomas et al., 2020), with resultant negative consequences in places as different as Kiribati (Donner and Webber, 2014) and Bangladesh (Hinkel et al., 2018). Donor-funded adaptation programs aimed at promoting behavioural change, e.g., through coastal planning or new decision-making systems, require enduring training and institutional capacity, which is difficult to upkeep after aid is depleted. Donor funding is often project-based and there are few avenues available to fund additional permanent and long-term staff needed to bolster climate change institutions. Without funding to support additional staff, existing institutions often lack the human capacity and resources needed for coastal adaptation (Ziervogel and Parnell, 2014).

C&S in the Global South also face financial challenges in addressing loss and damage due to climate-induced slow-onset and extreme events. Financial support to address both quantifiable damages and non-economic losses through measures such as climate resilient reconstruction after extreme weather events, and national and local level emergency contingency funds, is lacking and has been an issue of contention in international policy arenas (Bahinipati et al., 2017; Wewerinke-Singh and Salili, 2020; Martyr-Koller et al., 2021).

While coastal adaptation has largely been viewed as the responsibility of governments, private finance is increasingly recognized as necessary to help close the coastal adaptation funding gap (Ware and Banhalmi-Zakar, 2020). Financial arrangements for coastal adaptation measures that align public actor and private investor interests are suitable for a range of budgets, from US$10,000-100 million (Bisaro and Hinkel, 2018). Private equity instruments that involve real estate development companies have already been successfully implemented and are most effective in urban areas with high-value real estate development (Chiang and Ling, 2017). Public-private partnership equity instruments that engage construction and real estate developers have been successful for small- to medium-scale infrastructural projects. While public-private partnership bonds and public bonds have potential to align public actors and private investors, such instruments require de-risking of coastal adaptation through enabling economic policy instruments, such as concessional loans (Bisaro and Hinkel, 2018).

Explicitly identifying the benefits, or goods and services, that are provided by coastal adaptation is critical to supplement limited government funds and engage a broader set of financial tools and actors (Woodruff et al., 2020). Matching goods and services provided by particular adaptation strategies to specific beneficiaries helps identify the range of fair and equitable financial tools. In the Netherlands, public funding through state, regional and local entities have independent tax revenue systems to provide the funding needed to maintain flooding infrastructure (Hinkel et al., 2018).

Given the high costs of coastal adaptation, benefit to cost ratios (BCR) are often used to determine the value of investing in adaptation. BCR are high for urbanized coastal areas with high concentrations of assets (13% of the world's coastline), covering 90% of global coastal floodplain population and 96% of assets in the global coastal floodplain (Lincke and Hinkel, 2018). A global assessment shows BCR for investing in flood protection up to ~120 (Tiggeloven et al., 2020). For Europe, at least 83% of flood damages could be avoided by elevating dikes along ~23-32% of Europe's coastline and BCR vary from 8.3 to 14.9, with higher ratios for higher concentration pathways (Section 13.2) (Vousdoukas et al., 2020a). Globally 40% of damages can be reduced with levees of 1m and costs lower than avoided damage (Tamura et al., 2019). For a mix of expensive storm surge barriers, nature-based solutions and flood proofing measures for New York City, Aerts et al. (2014) found BCRs <1 for the current situation, but >2 for a SLR scenario of +1m.

However, BCR values may be low and adaptation investment may not be financially viable for small coastal settlements, less densely populated poorer coasts, or isolated communities *(medium confidence).* Considering BCR of protection and coastal migration across a range of SLR and SSP scenarios for the 21st century, a higher BCR was found for protection of only 3% of the global coastline protecting 78% of the coastal population and 92% of global coastal floodplain assets, while for the remaining coasts, coastal migration was estimated to be optimal in terms of economic costs (Lincke and Hinkel, 2021). Considering coastal migration as part of the solution space could lower global costs in investment and maintenance for SLR protection by a factor of 2-4 in the 21st century but would result in large land losses and high levels of migration for South and South-east Asia in particular and, in relative terms, small island nations would suffer most. The need to consider place attachment, community relationships, livelihoods and the spiritual and cultural significance of settlements limit the application of BCR as a tool for coastal adaptation decisions in these contexts (Thomas and Benjamin, 2020). Moreover, there is limited knowledge on trade-offs, including BCR, of alternative adaptation options and pathways at global to regional scale, in particular over the long-term (beyond 2100).

Even where BCR is high, finance may be inaccessible as it is challenging to convert the long-term benefits of adaptation into the revenue streams that may be needed to initially finance adaptation investments (Hinkel et al., 2018). For example, in Ho Chi Minh City, Vietnam, despite high BCR, high costs of flood protection (US$1.4-2.6 billion) have prevented such adaptation measures from being implemented (Hinkel et al., 2018; Cao et al., 2021). Moreover, drawing from places as distinct as small communities in Fiji (Neef et al., 2018) and Belize (Karlsson and Hovelsrud, 2015), and megacities like New York City and Shanghai (Oppenheimer et al., 2019), BCR provides only a limited view and consideration of feasibility, effectiveness, efficiency, equity, culture, politics and power, and attachment to place, is more likely to foster CRD (*high confidence*).

CCP2.4.3 Governance

An array of climate and non-climate perils (Le Cozannet et al., 2017), present coastal communities and their governing authorities with immense governance and institutional challenges that will get progressively more difficult as sea level rises (*high confidence*) (Wallace, 2017; Leal Filho et al., 2018; Oppenheimer et al., 2019). Yet a study of public provisions for coastal adaptation in 136 of the largest coastal port-urban agglomerations across 68 countries found no policy implementation in 50% of the cases; in 85% of cases, adaptation actions are not framed by current impacts or future risks; and formal efforts are recent and concentrated in more developed settings (Olazabal et al., 2019; Olazabal and Ruiz De Gopegui, 2021) - underscoring a persistent coastal adaptation gap. Translating these challenges into enabling governance conditions is difficult but instructive lessons are being learned, and summarized (from Table SMCCP2.4) for archetypal C&S in Tables CCP2.1, 2.2.

We start with a synopsis of governance settings within which coastal adaptation and CRD choices are made, and spotlight factors hindering and enabling translation of adaptation into practice. Then, building upon and extending the SROCC analysis of enablers and lessons learned in responding to SLR (Oppenheimer et al., 2019), we assess key governance challenges, related enablers and lessons learned (Tables CCP2.1, CCP2.2).

Governance arrangements and practices are embedded in the socio-political and institutional fabric of coastal C&S. Consequently, barriers and enablers for adapting to climate change at the coast, and charting pathways for CRD, reflect more general constraints and opportunities (*high confidence*) (Meerow, 2017; Rocle and Salles, 2018; Rosendo et al., 2018; Di Giulio et al., 2019; Hölscher et al., 2019; Van Assche et al., 2020; Williams et al., 2020). Local level action is often constrained; 231 cities in the USA report weak leadership, lack of funding and staffing, and low political will (Fu, 2020). A meta-analysis of coastal municipal planning documents in Australia shows few localities have moved beyond risk assessment (Bradley et al., 2015). Coastal C&S tend to prefer strategies that protect and accommodate existing coastline assets, i.e., a 'fix and forget' approach (Gibbs, 2015), rather than enduring proactive adaptation (Cooper and Pile, 2014).

Many C&S, especially in the Global South, already face high exposure to coastal risks, and development constraints associated with poverty and socioeconomic inequality, lack of transparent resource allocation mechanisms, and low political will (*high confidence*) (Di Giulio et al., 2019; Nagy et al., 2019; Pasquini, 2020; Lehmann et al., 2021). Research from across South America notes inadequate regulatory frameworks, missing data and information, widespread coastal ecosystem degradation, and complex interactions between natural disasters and civil conflict (Villamizar et al., 2017; Nagy et al., 2019). Coastal climate risks in the Global South are often compounded by ongoing land-use management conflicts and other pressures including informal land uses, unregulated and/or inadequate infrastructure/building development, public health priorities such as combating Dengue Fever, inadequate income diversification, low education levels, and political marginalization of communities historically not represented in the urban development process (Barbi and Ferreira, 2014; Salik et al., 2015; Cabral et al., 2017; Goh, 2019). There are also entrenched socio-economic inequalities leading to the maldistribution of adaptation actions and benefits in the Global North (Gould and Lewis, 2018; Keenan et al., 2018; Ranganathan and Bratman, 2019; Yumagulova, 2020; Long et al., 2021).

To address the myriad governance challenges attributed to low awareness, low skills, scalar mismatches, and high socioeconomic inequality and coastal vulnerability, post-AR5 research highlights enablers of more innovative approaches to bridge capacity, policy, and financial deficits (Reiblich et al., 2019) and facilitate more proactive implementation of coastal adaptation actions (Table SMCCP2.2; Fu, 2020). A survey of NGOs, state and local government across Alaska, Florida, and Maryland in the USA found that perceived risk, uncertainty, and trust in support for climate adaptation varied across two stages of adaptation – support for the development of plans and willingness to allocate human and financial resources to implement plans (Kettle and Dow, 2016). To bridge this gap, Cinner et al. (2018) suggest the need to build capacity across five domains: the assets that people can draw upon in times of need; the flexibility to change strategies and interventions; the ability to organize and act collectively; learning to recognize and respond to change (especially as important thresholds are approached); and the agency to determine whether to change or not, and then take prudent action).

Effective and accountable local leadership can help to mobilize capacities, resources, and climate awareness within coastal C&S. Strong leadership is associated with agenda-setting authorities and the ability to navigate complex institutional interests towards more strategic planning efforts (*high confidence*) (Ferguson et al., 2013; Anguelovski et al., 2014; Chu et al., 2017; Valdivieso and Andersson, 2018; Fink, 2019; Ndebele-Murisa et al., 2020). Policy leadership can positively influence the motivation and initiative of municipal officers (Lassa and Nugraha, 2014; Wijaya et al., 2020); whilst local leadership is needed integrate coastal management, disaster management and climate adaptation mandates (Rosendo et al., 2018).

Inclusive decision-making arrangements can enable participation, local ownership, and further equity in crafting coastal adaptation plans and policies (Chu et al., 2016). Inclusion of diverse stakeholders can help improve awareness of adaptation needs; help to bridge existing social inequalities in decision-making about adaption needs, options and outcomes; close the gap between formal and informal institutions, and engage Indigenous forms of decision-making, which often associate climate risks with livelihood, housing, and employment stressors (Ziervogel et al., 2016; Fayombo, 2020). For example, research from Pacific Island States (Nunn et al., 2017) and coastal Arctic zones (Romero Manrique et al., 2018) highlight the need to engage with Indigenous environmental knowledge. Case studies from Indonesia, Philippines, and Timor-Leste show that IKLK and customary laws can support environmental awareness, strengthen social cohesion, and help communities to better respond to climate impacts (Hiwasaki et al., 2015). Research from coastal Cambodia shows that inclusive governance arrangements can target empowerment of the most vulnerable groups to facilitate better adaptation behavior and mainstream adaption knowledge through both formal and informal education at the community level (Ung et al., 2016).

The law is key to governing climate risks in C&S, including regulating exposure to coastal hazards; facilitating accountable decision-making, funding arrangements, liabilities, and resolving disputes; and securing human rights (*high confidence*) (Setzer and Vanhala, 2019; Averill, 2020). But it has limits and can be an adaptation enabler and barrier (Green et al., 2015; Cosens et al., 2017; Craig et al., 2017; DeCaro et al., 2017). Contemporary legal practice has not enabled effective adaptation in part because SLR affects compensable property rights that are secured by the law and which generally trump concerns about public safety, resilience and sustainability (Reiblich et al., 2019). Private property rights can be used as both a sword and a shield to privilege dominant interests, by undermining land use policies, plans and implementation efforts intended to promote integrated coastal management and risk reduction (O'Donnell et al., 2019; Reiblich et al., 2019). Climate change litigation has proliferated over the last decade (Setzer and Vanhala, 2019), addressing, among other things, failures to prepare for or adapt to climate change, and to secure human rights (Peel and Osofsky, 2018). Reflexive and adaptive law that accounts for the distinctive features of coastal hazard risk, and associated governance imperatives, builds coastal C&S adaptive capacity and resilience (*high confidence*) (Garmestani and Benson, 2013; Cosens et al., 2017; DeCaro et al., 2017). Procedural justice, due process, and use of substantive standards instead of rules, provide legal stability and enable adaptation (Craig et al., 2017). Coastal adaptation efforts are ultimately implemented through C&S actions that are enabled or constrained by prevailing legislative, executive and judicial provisions and practices, which differ significantly across jurisdictions (He, 2018). In practice, the 'coastal lawscape' is made up of interconnected cultural-normative, political and legal systems that need to be understood holistically to enable coastal adaptation in C&S (O'Donnell, 2021).

Tables CCP2.1 and CCP2.2 summarise key insights about key governance challenges facing archetypal coastal C&S around the world, and associated critical enablers and lessons learned to address climate change-compounded coastal hazard risk (based on synthesis of Table SMCCP2.3).

Table CCP2.1: Governance challenges and critical enablers for addressing coastal hazard risk in C&S

Key governance challenges	Critical enablers for C&S to address coastal hazard risk
Complexity: Climate change compounds non-climatic hazard risks facing coastal C&S in interconnected, dynamic and emergent ways for which there are no simple solutions.	Draw on **multiple knowledge systems** to co-design and co-produce more acceptable, effective and enduring responses.
	Build **governance capacity** to tackle complex problems.
Time horizon and uncertainty: The future is uncertain, but climate change will continue for generations and cannot be addressed by short-term (e.g., 1-10 years) responses alone.	Adopt a **long-term view** but take action now. **Keep options open** to adjust responses as climate risk escalates and circumstances change
	Avoid new development commitments in exposed locations. Enable managed retreat in most at-risk locations by **anticipatory actions**, e.g., secure funds, legal provisions for buy-outs, resettlement, etc.
Cross-scale and cross-domain coordination: Decisions bound by jurisdictional and sectoral boundaries fail to address linkages within and between coastal ecosystems and C&S facing interconnected climate change compounded impacts and risk.	Develop networks and linkages within and between different governance scales and levels, and across policy domains and sectors, to improve **coordination**, build trust and legitimise decisions.
	Build **shared understanding** and enable locally appropriate responses through experimentation, innovation and social learning.
Equity and social vulnerability: Climate change compounds everyday inequity and vulnerability in coastal C&S, making it difficult to disentangle and address social drivers and root causes of risk.	Recognise political realities and **prioritise vulnerability**, justice and equity concerns to enable just, impactful and enduring outcomes.
	Strengthen **community capabilities** to respond to coastal hazard risk, using external assistance and government support if necessary.
Social conflict: Coastal C&S will be the focal point of contending views about appropriate climate responses; and face the challenge of avoiding destructive conflict and realising its productive potential.	Design and facilitate **tailor-made participation processes**, involving stakeholders early and consistently from negotiating responses to implementation.
	Create **safe arenas of engagement** for inclusive, informed and meaningful deliberation and collaborative problem-solving.

Table CCP2.2: Lessons learned from efforts to address coastal hazard risk

Lessons to address governance challenges and unlock enablers	**Archetypal C&S initiatives, constraints aside**
Complexity: Multiple knowledge systems – Reveal dynamic complexity drawing on multiple sources of locally relevant evidence – Use and integrate local, Indigenous and scientific knowledge – Include marginalised voices and knowledges of vulnerable groups, women, young people, etc. – Build shared understanding through storytelling – Bridge gaps between science, policy and practice by experimenting with novel approaches and working across organisational, sectoral and institutional boundaries	**Seychelles (0.1mill; open coast):** Science-policy-local knowledge partnerships to co-produce usable information for decision-making. **Dhaka, Bangladesh (21mill; delta):** Climate change is national priority. Partnering with Netherlands to develop long-term data plans. **Jakarta, Indonesia (10.8mill; delta):** Community-based efforts to foster mutual assistance and self-organisation. **Utqiagvik (formerly Barrow) Alaska, USA (0.04 mill; Arctic, open coast):** Using local knowledge and historical precedent of transformative change to integrate local and scientific knowledge.
Complexity: Governance capacity – Joined-up visionary leadership is key, e.g., cabinet- and C&S-level commitments to long-term implementation – Translate political will into substantial dedicated budgets to build government capacity to tackle complex problems – Use flexible approaches to build resilience, e.g., independent agency alongside traditional administrative bodies – Counter deadlocks due to short-term priorities and vested interests with long-term perspective, considering plausible scenarios and incentivising novel solutions – Translate national requirements into local action with enabling provisions for tailored local policy and practice – Tackle emergent problems by setting up enduring monitoring and lesson-learning processes – Governance arrangements reconcile competing interests in inclusive, timely and legitimate manner – Make visible and reflect on underlying reasons for policy actions / inaction, including values, attitudes and taken for granted habits influencing problem-solving capability	**Singapore (5.6mill; open coast):** Integrated approach across Ministries committing to long-term adaptation (and mitigation goals) by 2030. **Rotterdam, Netherlands (0.65mill; delta):** Delta Programme, supported by law, administrative arrangements, and €1bill pa budget to 2029. **Florianopolis, Santa Catarina island, Brazil (1.2mill; mixed):** Building knowledge hub via public-private-civil society partnerships. **Nassau, Bahamas (0.275mill; open coast, small island):** Identifying responsibilities, accessing funding, and preparing adaptation plans drawing on evidence-based studies. **Shanghai (27mill; estuary), China:** Contain risk by combining long-term planning, political will, and national and municipal provisions, and technical capability. **Can Tho City, Vietnam (0.4 mill; delta):** Engage international donors and research community.
Time horizon and uncertainty: Long-term view – Establish national policies and guidance with long-term view (e.g., 100 years) that enables action now – Develop shared medium- (10-50 years) to long-term vision (100+ years) – Use adaptation pathways approach to make short-term decisions consistent with long-term goals – Meaningfully involve stakeholders, e.g., involve representatives in decision-making – Address power imbalances and human development needs, e.g., in goal-setting and process design – Reconcile divergent perspectives through tailored responses	**Napier (65k), Hawkes Bay (178.6k; open coast), New Zealand:** National law compels local authorities to take 100-year perspective; 2100 Strategy accounts for dynamic complexity and uncertain future through adaptation pathways. **Shanghai, China (27mill; estuary):** Plans up to 2100, strong national and municipal focus on climate change, and access to technical expertise. **Dhaka, Bangladesh (21mill; delta):** Long term adaptation plans through to 2100.
Time horizon and uncertainty: Avoidance and anticipatory action – Avoid development in exposed localities using spatial plans – Use window of opportunity created by extreme events – Prepare pre-event plans and tailor risk reduction and resilience building post-disaster – Reveal political pressures and opposition that hamper efforts to address intolerable risk and unacceptable impacts	**Rotterdam, Netherlands (0.65mill; delta):** Delta Programme promotes 'living with water', allowing and managing urban flooding. **Napier (65k), Hawkes Bay, New Zealand (178.6k, open coast):** Regulatory provisions discourage new development in high-risk locations; strategy sequences adaptation interventions. **Florianopolis, Santa Catarina island, Brazil (1.2mill; mixed):** Research reveals unregulated ad hoc development in at-risk locations preventing effective adaptation.
Cross-scale and cross-domain coordination: Coordination – Collaborative projects involve state and non-state actors	**Seychelles (0.1mill; open coast, small island):** Cross-sectoral and institutional collaboration to improve use of limited financial resources; and

– Multi-lateral agreements, e.g., between neighbouring countries, coastal regions and C&S – Connect people, organizations and communities through boundary spanning organizations – Leadership by central actors with capable teams is key – Mobilise the capabilities of communities and non-state actors – Address policy inconsistencies and clarify roles and responsibilities – Secure national and regional resources to support local efforts – Use measures to promote interaction, deliberation and coordination to manage spill-over effects – Strengthen linkages between formal (e.g., regulatory) and informal (e.g., traditions and rituals) institutions, e.g., through information sharing – Use spatial coordination mechanisms, e.g., land-use planning, to translate national and regional provisions into local competencies	community-based and ecosystem-based adaptation to bridge adaptation and mitigation and improve coordination. **Florianopolis, Santa Catarina island, Brazil (1.2mill; mixed):** Effective local climate action hampered by governance constraints and weak federal leadership. **Cape Town, South Africa (4.6mill; mixed):** Multi-level climate governance advanced at local-provincial level, but political turf-battles hamper national-provincial-local progress.
Cross-scale and cross-domain coordination: Shared understanding – Prioritise social learning and shared understanding, e.g., accessible information to all, irrespective of education, language, etc. – Account for local history, culture and politics through engagement, experimentation and innovation – Generate socio-economic, livelihood and climate-development co-benefits – Leverage national and trans-national community and local authority networks	**Cape Town, South Africa (4.6mill; mixed):** Capable local leaders collaborate with researchers in municipality-initiated community-based adaptation. Translating plans into action challenging given 'everyday' vulnerability exacerbated by climate change impacts. **New York City, USA (23.5mill; mixed):** State and city government work with communities to build adaptive capacity and resilience, drawing on technical capabilities but many challenges.
Equity and social vulnerability: Address vulnerability – Expose drivers and root causes of injustice, structural inequity and vulnerability – Link human development concerns, risk reduction, resilience and adaptation – Raise awareness and public support for actions that are just and equitable – Understand discriminatory drivers (e.g., on racial grounds) of coastal land-use patterns and risk – Address barriers facing marginalised groups – Use inclusive planning, decision-making and implementation processes that give voice to vulnerable people	**Cape Town, South Africa (4.6mill; mixed):** Adaptation framed by apartheid legacy; focus on reducing vulnerability, public safety and securing critical infrastructure and community assets. **Maputo-Matola, Mozambique (3mill; mixed):** Livelihood opportunities compromised by ecological degradation compelling community DIY coping in face of severe poverty and vulnerability, and weak governance and institutional capacity, and reliance on donors. **New York City, USA (23.5mill; estuary):** Hurricane Sandy (2012) focused attention on climate risk and plight of exposed and vulnerable people, and sparked adaptation action.
Equity and social vulnerability: Community capabilities – Raise vulnerability and risk awareness and understanding, build community capability and leverage external support by working with professionals, academics, local NGOs, journalists and activists – Secure rights of vulnerable groups through court action where necessary – Integrate traditional community responses with local government efforts – Ensure gender equity, e.g., representation on planning and decision-making bodies	**Monkey River village, Belize (200 people; estuary):** Remote Indigenous community capacity to tackle erosion enabled by interventions by researchers, journalists and local NGOs to secure media and political attention after hurricane damage. **Accra, Ghana (2.5mill; delta):** Household adaptation mediated by local government flood mitigation efforts; need better early warning and maintain local stormwater to prevent flooding. **Lagos, Nigeria (14 mill; open coast):** Building adaptive capacity to overcome 'everyday' vulnerability and poverty severely challenging.
Social conflict: Tailor-made participation – Create opportunities for integrative and inclusive solutions – Use conflict resolution mechanisms	**Napier (65k), Hawkes Bay, New Zealand (178.6k people, open coast):** Collaboration between local authorities and Indigenous People (Māori), involving stakeholders, led to co-designed

– Appoint independent facilitators / mediators and involve officials as 'bureaucratic activists' to improve inclusivity and iterative and reflexive engagement – Align informal participatory processes with statutory processes and government practices – Sustain engagement by securing resources for local use, and aligning activities with political and bureaucratic cycles – Involve historically disadvantaged and socially vulnerable groups, e.g., accessible meeting locations / venues, local languages and culturally appropriate meeting protocols – Involve local leaders who will champion adaptation and help mainstream findings into C&S decision-making – Inclusive processes help address conflict and drivers of vulnerability, and promote just adaptation	long-term strategy with implementation commitment. **Manila, Philippines (14mill; open coast):** Metro-wide planning and infrastructure provisions that foster climate justice and resilience explored; with community-based actions.
Social conflict: Safe arenas of engagement – Use flexible and enabling processes based in local institutions that are robust and fair, supported by governing authorities – Attend to local social dynamics and reduce elite domination – Use local and Indigenous knowledge and science – Use institutional improvisation to address local concerns – Use trusted independent facilitators – Incentivise participation by disadvantaged groups – Focus on improving risk literacy, optimism and capacity for joint problem-solving – Use joint, collaborative activities to facilitate public dialogue, and secure institutional support for action – Enable ongoing deliberation and social learning – Make continual adjustments as circumstances change, e.g., build shared understanding about locally relevant thresholds beyond which alternative courses of action need to be actioned.	**Napier (65k), Hawkes Bay, New Zealand (178.6k people, open coast):** Active involvement of local communities, Indigenous People (Māori) and research community to co-produce fit-for-purpose long-term coastal hazard risk strategy. **Rotterdam, Netherlands (0.65mill; delta):** Delta Programme institutionalised multi-level adaptation governance with strong accountability mechanisms. **Greater London, UK (8.9mill; estuary):** Long-term provisions for at-risk Thames Estuary, including major protective works, embedded in Greater London Spatial Development Plan and London Climate Change Partnership championed by strategic leadership, and supported by the public and strong technical capability.

In sum, prospects for addressing climate risk in archetypal coastal C&S around the world depend on the extent to which societal choices, and associated governance processes and practices, address the drivers and root causes of exposure and social vulnerability (*very high confidence*). Coastal C&S are more able to address these challenges when authorities work with local communities, and vulnerable groups in particular, and with stakeholders from the local to national level and beyond, to chart adaptation pathways that enable sustained reduction in the exposure and vulnerability of those most at risk *(very high confidence)* (Cross-Chapter Box SLR in Chapter 3; Magnan et al., 2019; Oppenheimer et al., 2019). Unlocking potential enablers for locally appropriate and effective adaptation is difficult because many drivers and root causes of coastal risk are historically and institutionally embedded *(high confidence)* (Thomas et al., 2019). Charting credible, salient and legitimate adaptation pathways is consequently a struggle in reconciling divergent worldviews, values and interests (Sovacool, 2018; Mendenhall et al., 2020; Bowden et al., 2021a; Bowden et al., 2021b). Unlocking the productive potential of conflict is foundational for transitioning towards pathways that foster CRD *(high confidence)* (Abrahams and Carr, 2017; Harris et al., 2018; Sharifi, 2020). But this can be especially challenging for low-lying coastal C&S characterised by degraded coastal ecosystems susceptible to climate change impacts as well as pronounced inequity and governance constraints *(high confidence)* (Esteban et al., 2017; Jones et al., 2020).

CCP2.4.4 Enabling Climate Resilient Development for Cities and Settlements by the Sea

The above critical enablers, and lessons learned from around the world, establish a strong foundation for charting pathways for CRD in coastal C&S. These pathways will necessarily vary in different C&S, and synergies and commonalities within different coastal archetypes can be leveraged. Pivotal is recognition of the narrow window of time remaining to translate embryonic risk assessment and adaptation planning into concerted implementation efforts. C&S by the sea could be the centres of innovation that lead the way to advancing SDGs through to 2030, and CRD beyond this decade (see Section 2.1.1).

This CCP shows that a range of adaptation solutions; hard and soft protection, nature-based measures, accommodate, advance, retreat, and behavioural change will need to be implemented as an integrated and sequenced portfolio of responses if coastal C&S are to contain the adverse risks of climate change (*high confidence*). The effectiveness and feasibility of any intervention, at a given moment, to reduce a particular climate-compounded coastal hazard risk, or combination of risks, depend upon the settlement archetype; including its geomorphological, cultural, economic, technical, institutional, and political features, and historical development trajectory. Coastal C&S will benefit from developing flexible adaptation pathways - sequences of adaptation strategies and intervention options - to navigate a dynamic solution space that changes in response to climate and other drivers of change, and is also shaped by human development choices, and socio-economic, technological and institutional change.

There is no silver bullet or panacea. But developing locally appropriate, yet flexible, pathways for CRD will help coastal communities address escalating risks and uncertainty (Cross-Chapter Box DEEP in Chapter 17). Effective pathways are based on robust integrated information about dynamic coastal hazard risk and plausible interventions. However, their successful implementation requires multi-scale governance arrangements and practices able to bridge different administrative and sectoral capacities in the coastal zone; effective and accountable leadership; and inclusive decision-making arrangements to enable participation, manage conflicts and trade-offs; engender local ownership, and promote equity and justice in coastal adaptation plans and policies. Further, the feasibility of adaptation strategies and interventions, especially those entailing changing behaviours and practices, is increased by recognising and incorporating peoples' values and beliefs and Indigenous and Local knowledge systems, as well as the voices of women and vulnerable groups.

Coastal C&S are on the frontline of observed climate change impacts and future risk (*high confidence*). Difficult choices will be made as climate- and ocean-driven extremes become more frequent. In the next few decades, many coastal regions and C&S will have the opportunity to take actions to avoid and reduce risk, through incremental as well as more transformative interventions. Under higher levels of global warming, decisions will need to be made faster or respond to higher levels of SLR (*high confidence*) (Cross-Chapter Box SLR in Chapter 3). This is particularly challenging in coastal C&S characterised by inertia and path-dependency of development choices, with long lead times for adaptation planning and implementation, and the long design life and societal impact of many interventions. Given the risks assessed in coastal C&S, the scale of climate impacts globally will depend to a large extent on whether coastal settlements develop and implement pre-emptive and flexible adaptation pathways, and whether significant and timely reduction in greenhouse gas emissions is achieved in C&S and globally *(high confidence).*

[START FAQ CCP2.1 HERE]

FAQ CCP2.1: Why are coastal cities and settlements by the sea especially at risk in a changing climate, and which cities are most at risk?

Coastal cities and settlements (C&S) by the sea face much greater risk than comparable inland C&S because they concentrate a large portion of global population and economic activity whilst being exposed and vulnerable to a range of climate- and ocean-compounded hazard risk driven by climate change. Coastal C&S range from small settlements along waterways and estuaries, to small island states with maritime populations and/or beaches and atolls that are major tourist attractions, to large cities that are major transport and financial hubs in coastal deltas, and mega-cities and even mega-regions with several coastal mega-cities.

The concentration of people, economic activity and infrastructure dynamically interact with coast-specific hazards magnifying the exposure of these C&S to climate risks. While large inland cities and coastal settlements can be exposed to climate-driven hazards, such as urban heat islands and air pollution, the latter are also subject to distinctive ocean-driven hazards, such as rising sea levels, exposure to tropical cyclones and storm surges, flooding from extreme tides, and land subsidence from decreased sediment deposition along coastal deltas and estuaries. With climate change increasing the intensity and frequency of hazards under all future warming levels, the risks to lives, livelihoods and property are especially acute in C&S by the sea.

Coastal cities are diverse in shape, size, growth patterns and trajectories, and access to cultural, financial, and ecosystem resources and services. Along deltaic and estuarine archetypes, cities most vulnerable to a changing climate have relatively high levels of poverty and inequality, in terms access to resources and ecosystem services, and large populations and dense built environments translating into higher exposure to coastal climate risks.

These climate risks at the coast can also be magnified by compounding and cascading effects due to non-climate drivers directly affecting vulnerable peri- and ex-urban areas inland. These risks include disruption to transport supply chains and energy infrastructure from airports and power plants sited along coastal areas, as occurred in New York City, USA, during Hurricane Sandy in 2012. The impacts can be felt around the world through globalized economic and geopolitical linkages, e.g., through maritime trade and port linkages.

For open coasts, settlements on low-lying small island states and the Arctic are especially vulnerable to climate change, and sea level rise impacts in particular, well before 2100. While the economic risks may not compare to the scale of those faced in coastal megacities with high per capita GDP, the existential risks to some nations and an array of distinctive livelihoods, cultural heritage, and ways-of-life in these settlements are great, even with modest sea level rise.

[END FAQ CCP2.1 HERE]

[START FAQ CCP2.2 HERE]

FAQ CCP2.2: What actions can be taken by coastal cities and settlements to reduce climate change risk?

Sea level rise responds to climate change over long timeframes and will continue even after successful mitigation. However, rapid global mitigation of greenhouse gases significantly reduces risks to coastal C&S, and crucially buys time for adaptation.

Appropriate actions to reduce climate change risks on coastal C&S depend on the scale and speed of coastal change interacting with unfolding local circumstances – reflecting the hazards, exposure, vulnerability, and response to risks.

'Hard' protection, like dikes and seawalls, can reduce risks of flooding for several metres of sea-level rise in some coastal C&S. These are most cost-effective for densely populated cities and some islands but may be unaffordable for poorer regions. Although these measures reduce the likelihood of coastal flooding, residual risk remains, and hard protection typically has negative consequences for natural systems. In low-lying protected coastal zones, draining river and excess water will increasingly be hampered, requiring pumping eventually or transferring to alternative strategies.

Whereas structures can disrupt natural beach morphology processes, sediment-based protection replenishes beaches. These have lower impact on adjacent beaches and coastal ecology and lower costs for construction and maintenance compared to hard structures. Another form of 'soft' protection involves establishing, rehabilitating and preserving coastal ecosystems, like marshes, mangroves, seagrass, coral reefs and dunes, providing 'soft' protection against storm surges, reducing coastal erosion, and offering additional benefits including food, materials, and carbon sequestration. However, these are less effective where there is limited space in the coastal zone, limited sediment supply, and under higher rates of sea level rise.

Coastal settlements can 'avoid' new flood and erosion risk by preventing development in areas exposed to current and future coastal hazards. Where development already exists, settlements can 'accommodate' climate change impacts through, among other things, land use zoning, raising ground or buildings above storm surge levels, installing flood proofing measures within and outside properties, and early warning systems. Improving the capacity of urban drainage, incorporating nature-based solutions within urban areas, and managing land upstream of settlements to reduce runoff from the hinterland, reduces the risk of compound flood events. More radically, land can also be reclaimed from the sea, which offers opportunities for further development but has impacts on the natural system and wider implications for the trajectory of development.

Coastal risks and impacts such as floods, loss of fisheries or tourism, or salinization of groundwater, require people to change behaviour to adapt, such as diversifying livelihoods or moving away from low-lying areas. Currently most of these practices are reactive and help people adjust to/cope with current impacts. While a critical part of coastal adaptation, changing behaviour is most likely when enabled by supportive policies and financial structures, and alignment with socio-cultural values and worldviews.

Where risks are very high, or resources are insufficient to manage risks, submergence or erosion of coastal C&S will be inevitable, requiring 'retreat' from the coastline. This is the outlook for millions of people in coming decades, including those living in river deltas, Arctic communities, small islands, and low-lying small settlements in poor and wealthy nations. Whilst the impacts of retreat on communities can be devastating, the prospect of many C&S and even whole nations being permanently inundated in coming centuries underscores the imperative for urgent action.

Crucial to making choices about how to mitigate greenhouse gas emissions, and adapt to climate change in coastal C&S, is to establish institutions and governance practices supporting climate resilient development – a mix and sequence of mitigation and adaptation actions - that are fair, just, and inclusive as well as technically and economically effective across successive generations.

[END FAQ CCP2.2 HERE]

[START FAQ CCP2.3 HERE]

FAQ CCP2.3: Considering the wide-ranging and interconnected climate and development challenges coastal cities and settlements face, how can more climate resilient development pathways be enabled?

Coastal C&S are on the frontline of the climate change challenge. They are the interface of three interconnected realities. First, they are critical nodes of global trade, economic activity and coast-dependent livelihoods, all of which are highly and increasingly exposed to climate- and ocean-driven hazards (FAQ CCP2.1). Second, coastal C&S are also sites where some of the most pressing development challenges are at play (e.g., trade-offs between expanding critical built infrastructure while protecting coastal ecosystems, high economic growth coupled with high inequality in some coastal megacities). Third, coastal C&S are also centres of innovation and creativity, thus presenting a tremendous opportunity for climate action through a range of infrastructural, nature-based, institutional, and behavioural solutions (FAQ CCP2.2). Given these three realities of high climate change risks, rapid but contested and unequal development trajectories, and high potential for innovative climate action, C&S are key to charting pathways for Climate Resilient Development.

Three key levers can enable pathways that are climate-resilient and meet goals of inclusive, sustainable development. One is to enable climate resilient development is flexible, proactive, and transparent governance systems, built on a bedrock of accountable local leadership, evidence-based decision-making, even under uncertainty, and inclusive institutions that consider different stakeholder voices and knowledge systems. Another key enabler is acknowledging the socio-cultural and psychological barriers to climate action and incentivising people to change lifestyles and behaviours that are pro-climate and aligned with community-oriented values and norms. In practice, coastal C&S are experimenting with different strategies to change practices and behaviours, such as using subsidies and zoning policies, tax rebates and public awareness campaigns, to promote individual and collective action. Finally, enabling climate resilient development needs dedicated, short- and long-term financing to reorient current trajectories of unsustainable and unequal development towards climate mitigation and adaptation action that reduces current and predicted losses and damages, especially in highly vulnerable coasts, such as the small island states, the

Arctic and low-lying C&S. Currently, adaptation finance is concentrated in coastal megacities and tends to be deployed in risk-proofing high-value waterfront properties or key infrastructures. Addressing these finance imbalances (globally, regionally, and sub-nationally) remains a critical barrier to inclusive climate resilient coastal development.

Notwithstanding the many interconnected challenges faced, from more frequent and intense extreme events to the COVID-19 pandemic, many coastal C&S are experimenting with ways to pivot towards climate resilient development. Critical enablers have been identified and lesson learned which, if translated into practice, will enhance the prospects for advancing the SDGs and charting pathways for Climate Resilient Development that are appropriate to local contexts and foster human well-being and planetary health.

References

Abadie, L. M. et al., 2020: Comparing urban coastal flood risk in 136 cities under two alternative sea-level projections: RCP 8.5 and an expert opinion-based high-end scenario. *Ocean & Coastal Management*, **193**, 105249, doi:https://doi.org/10.1016/j.ocecoaman.2020.105249.

Abrahams, D. and E. R. Carr, 2017: Understanding the Connections Between Climate Change and Conflict: Contributions From Geography and Political Ecology. *Current Climate Change Reports*, **3** (4), 233-242, doi:10.1007/s40641-017-0080-z.

Achete, F., M. van der Wegen, J. A. Roelvink and B. Jaffe, 2017: How can climate change and engineered water conveyance affect sediment dynamics in the San Francisco Bay-Delta system? *Climatic Change*, **142** (3), 375-389, doi:10.1007/s10584-017-1954-8.

Adger, W. N. et al., 2020: Urbanization, Migration, and Adaptation to Climate Change. *One Earth*, **3** (4), 396-399, doi:https://doi.org/10.1016/j.oneear.2020.09.016.

Aerts, J. C. et al., 2018: Pathways to resilience: adapting to sea level rise in Los Angeles. *Annals of the New York Academy of Sciences*, **1427** (1), 1-90, doi:doi:10.1111/nyas.13917.

Aerts, J. C. J. H. et al., 2014: Evaluating Flood Resilience Strategies for Coastal Megacities. *Science*, **344** (6183), 473-475, doi:10.1126/science.1248222.

Ajibade, I., 2019: Planned retreat in Global South megacities: disentangling policy, practice, and environmental justice. *Climatic Change*, **157** (2), 299-317, doi:10.1007/s10584-019-02535-1.

Alexander, K. S., A. Ryan and T. G. Measham, 2012: Managed retreat of coastal communities: understanding responses to projected sea level rise. *Journal of Environmental Planning and Management*, **55** (4), 409-433, doi:10.1080/09640568.2011.604193.

Allison, E. H. and H. R. Bassett, 2015: Climate change in the oceans: Human impacts and responses. *Science*, **350** (6262), 778-782, doi:10.1126/science.aac8721.

Alves, B., D. B. Angnuureng, P. Morand and R. Almar, 2020: A review on coastal erosion and flooding risks and best management practices in West Africa: what has been done and should be done. *Journal of Coastal Conservation*, **24** (3), 38, doi:10.1007/s11852-020-00755-7.

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.

Anguelovski, I., E. Chu and J. Carmin, 2014: Variations in approaches to urban climate adaptation: Experiences and experimentation from the global South. *Global Environmental Change*, **27**, 156-167, doi:https://doi.org/10.1016/j.gloenvcha.2014.05.010.

Arabadzhyan, A. et al., 2020: Climate change, coastal tourism, and impact chains – a literature review. *Current Issues in Tourism*, 1-36, doi:10.1080/13683500.2020.1825351.

Araos, M. et al., 2016: Climate change adaptation planning in large cities: A systematic global assessment. *Environmental Science & Policy*, **66**, 375-382, doi:10.1016/j.envsci.2016.06.009.

Araos, M. et al., 2017: Climate change adaptation planning for Global South megacities: the case of Dhaka. *Journal of Environmental Policy & Planning*, **19** (6), 682-696, doi:10.1080/1523908X.2016.1264873.

Arkema, K. K. et al., 2017: Linking social, ecological, and physical science to advance natural and nature-based protection for coastal communities. *Annals of the New York Academy of Sciences*, **1399** (1), 5-26, doi:10.1111/nyas.13322.

Auerbach, L. W. et al., 2015: Flood risk of natural and embanked landscapes on the Ganges–Brahmaputra tidal delta plain. *Nature Climate Change*, **5**, 153, doi:10.1038/nclimate2472
https://www.nature.com/articles/nclimate2472#supplementary-information.

Avelino, J. E. et al., 2018: Survey tool for rapid assessment of socio-economic vulnerability of fishing communities in Vietnam to climate change. *Geosciences*, **8** (12), 452, doi:https://doi.org/10.3390/geosciences8120452.

Averill, M., 2020: Climate Litigation: Ethical Implications and Societal Impacts. *Denver Law Review*, **85** (4), 899.

Bahinipati, C. S., U. Rajasekar, A. Acharya and M. Patel, 2017: Flood-induced Loss and Damage to Textile Industry in Surat City, India. *Environment and Urbanization ASIA*, **8** (2), 170-187, doi:10.1177/0975425317714903.

Bakkensen, L. A. and R. O. Mendelsohn, 2019: Global Tropical Cyclone Damages and Fatalities Under Climate Change: An Updated Assessment. In: Hurricane Risk [Collins, J. M. and K. Walsh (eds.)]. Springer International Publishing, Cham, 179-197.

Bangalore, M., A. Smith and T. Veldkamp, 2019: Exposure to Floods, Climate Change, and Poverty in Vietnam. *Economics of Disasters and Climate Change*, **3** (1), 79-99, doi:10.1007/s41885-018-0035-4.

Barbi, F. and L. d. C. Ferreira, 2014: Risks and political responses to climate change in Brazilian coastal cities. *Journal of Risk Research*, **17** (4), 485-503, doi:10.1080/13669877.2013.788548.

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.

Barragán, J. M. and M. de Andrés, 2015: Analysis and trends of the world's coastal cities and agglomerations. *Ocean & Coastal Management*, **114**, 11-20, doi:10.1016/j.ocecoaman.2015.06.004.

Becker, A., A. K. Y. Ng, D. McEvoy and J. Mullett, 2018: Implications of climate change for shipping: Ports and supply chains. *WIREs Climate Change*, **9** (2), e508, doi:10.1002/wcc.508.

Bell, A. R. et al., 2021: Migration towards Bangladesh coastlines projected to increase with sea-level rise through 2100. *Environmental Research Letters*, **16** (2), 024045, doi:10.1088/1748-9326/abdc5b.
Bendixen, M. et al., 2021: Sand, gravel, and UN Sustainable Development Goals: Conflicts, synergies, and pathways forward. *One Earth*, **4** (8), 1095-1111, doi:https://doi.org/10.1016/j.oneear.2021.07.008.
Bendixen, M. et al., 2019: Promises and perils of sand exploitation in Greenland. *Nature Sustainability*, **2** (2), 98-104, doi:10.1038/s41893-018-0218-6.
Bhattacharya, J., 1978: Deltas and estuaries. In: Sedimentology. Springer Berlin Heidelberg, Berlin, Heidelberg, 310-322.
Bindoff, N. et al., 2019: Changing ocean, marine ecosystems, and dependent communities. In: IPCC special report on the ocean and cryosphere in a changing climate.
Binh, P. T., X. Zhu, R. A. Groeneveld and E. C. van Ierland, 2020: Risk communication, women's participation and flood mitigation in Vietnam: An experimental study. *Land Use Policy*, **95**, 104436, doi:https://doi.org/10.1016/j.landusepol.2019.104436.
Bisaro, A. and J. Hinkel, 2018: Mobilizing private finance for coastal adaptation: A literature review. *WIREs Climate Change*, **9** (3), e514, doi:10.1002/wcc.514.
Blackburn, S., M. Pelling and C. Marques, 2019: Megacities and the Coast: Global Context and Scope for Transformation. In: Coasts and Estuaries. Elsevier, 661-669.
Boas, I. et al., 2019: Climate migration myths. *Nature Climate Change*, **9** (12), 901-903, doi:10.1038/s41558-019-0633-3.
Bohnet, I. C. and P. L. Pert, 2010: Patterns, drivers and impacts of urban growth—A study from Cairns, Queensland, Australia from 1952 to 2031. *Landscape and Urban Planning*, **97** (4), 239-248, doi:10.1016/j.landurbplan.2010.06.007.
Bowden, V., D. Nyberg and C. Wright, 2021a: Truth and power: deliberation and emotions in climate adaptation processes. *Environmental Politics*, **30** (5), 708-726, doi:10.1080/09644016.2020.1850972.
Bowden, V., D. Nyberg and C. Wright, 2021b: "We're Going Under": The Role of Local News Media in Dislocating Climate Change Adaptation. *Environmental Communication*, **15** (5), 625-640, doi:10.1080/17524032.2021.1877762.
Bradley, M., I. van Putten and M. Sheaves, 2015: The pace and progress of adaptation: Marine climate change preparedness in Australia's coastal communities. *Marine Policy*, **53**, 13-20, doi:https://doi.org/10.1016/j.marpol.2014.11.004.
Bradt, J., 2019: Comparing the effects of behaviorally informed interventions on flood insurance demand: an experimental analysis of 'boosts' and 'nudges'. *Behavioural Public Policy*, 1-31, doi:10.1017/bpp.2019.31.
Brodie, J. and R. G. Pearson, 2016: Ecosystem health of the Great Barrier Reef: Time for effective management action based on evidence. *Estuarine, Coastal and Shelf Science*, **183**, 438-451, doi:10.1016/j.ecss.2016.05.008.
Brown, S. et al., 2018: Quantifying Land and People Exposed to Sea-Level Rise with No Mitigation and 1.5°C and 2.0°C Rise in Global Temperatures to Year 2300. *Earth's Future*, **6** (3), 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), e12567, doi:10.1111/jfr3.12567.
Brown, S. I., M. E. Dickson, P. S. Kench and R. J. Bergillos, 2019: Modelling gravel barrier response to storms and sudden relative sea-level change using XBeach-G. *Marine Geology*, **410**, 164-175, doi:10.1016/j.margeo.2019.01.009.
Bruine de Bruin, W., G. Wong-Parodi and M. G. Morgan, 2014: Public perceptions of local flood risk and the role of climate change. *Environment Systems and Decisions*, **34** (4), 591-599, doi:10.1007/s10669-014-9513-6.
Bubeck, P. et al., 2017: Explaining differences in flood management approaches in Europe and in the USA – a comparative analysis. *Journal of Flood Risk Management*, **10** (4), 436-445, doi:https://doi.org/10.1111/jfr3.12151.
Buchanan, M. K., M. Oppenheimer and A. Parris, 2019: Values, bias, and stressors affect intentions to adapt to coastal flood risk: a case study from New York City. *Weather, Climate, and Society*, **11** (4), 809-821, doi:10.1175/WCAS-D-18-0082.1.
Buchori, I. et al., 2018: Adaptation to coastal flooding and inundation: Mitigations and migration pattern in Semarang City, Indonesia. *Ocean & Coastal Management*, **163**, 445-455, doi:https://doi.org/10.1016/j.ocecoaman.2018.07.017.
Buddemeier, R. W. et al., 2008: Coastal typology: An integrative "neutral" technique for coastal zone characterization and analysis. *Estuarine, Coastal and Shelf Science*, **77** (2), 197-205, doi:10.1016/j.ecss.2007.09.021.
Buser, M., 2020: Coastal Adaptation Planning in Fairbourne, Wales: lessons for Climate Change Adaptation. *Planning Practice & Research*, **35** (2), 127-147, doi:10.1080/02697459.2019.1696145.
Buurman, J. and V. Babovic, 2016: Adaptation Pathways and Real Options Analysis: An approach to deep uncertainty in climate change adaptation policies. *Policy and Society*, **35** (2), 137-150, doi:10.1016/j.polsoc.2016.05.002.
Cabral, P. et al., 2017: Assessing Mozambique's exposure to coastal climate hazards and erosion. *International Journal of Disaster Risk Reduction*, **23**, 45-52, doi:https://doi.org/10.1016/j.ijdrr.2017.04.002.
Camus, P. et al., 2019: Probabilistic assessment of port operation downtimes under climate change. *Coastal Engineering*, **147**, 12-24, doi:https://doi.org/10.1016/j.coastaleng.2019.01.007.

Cao, A. et al., 2021: Decoupled formal and informal flooding adaptation and conflicts in coastal cities: A case study of Ho Chi Minh City. *Ocean & Coastal Management*, **209**, 105654, doi:https://doi.org/10.1016/j.ocecoaman.2021.105654.

Carey, J., 2020: Core Concept: Managed retreat increasingly seen as necessary in response to climate change's fury. *Proceedings of the National Academy of Sciences*, **117** (24), 13182-13185, doi:10.1073/pnas.2008198117.

CCC, 2017: *Managing the coast in a changing climate*. Committee on Climate Change, London.

CEIC. 2021: Census and Economic Information Center. [Available at: https://www.ceicdata.com/en]

Chan, F. K. S. et al., 2018: Towards resilient flood risk management for Asian coastal cities: Lessons learned from Hong Kong and Singapore. *Journal of Cleaner Production*, **187**, 576-589, doi:https://doi.org/10.1016/j.jclepro.2018.03.217.

Chausson, A. et al., 2020: Mapping the effectiveness of nature-based solutions for climate change adaptation. *Global Change Biology*, **26** (11), 6134-6155, doi:10.1111/gcb.15310.

Chiang, Y.-C. and T.-Y. Ling, 2017: Exploring Flood Resilience Thinking in the Retail Sector under Climate Change: A Case Study of an Estuarine Region of Taipei City. *Sustainability*, **9** (9), 1650.

Christodoulou, A., P. Christidis and H. Demirel, 2019: Sea-level rise in ports: a wider focus on impacts. *Maritime Economics & Logistics*, **21** (4), 482-496, doi:10.1057/s41278-018-0114-z.

Christopher Small and Joel E. Cohen, 2004: Continental Physiography, Climate, and the Global Distribution of Human Population. *Current Anthropology*, **45** (2), 269-277, doi:10.1086/382255.

Chu, E., I. Anguelovski and J. Carmin, 2016: Inclusive approaches to urban climate adaptation planning and implementation in the Global South. *Climate Policy*, **16** (3), 372-392, doi:10.1080/14693062.2015.1019822.

Chu, E., I. Anguelovski and D. Roberts, 2017: Climate adaptation as strategic urbanism: assessing opportunities and uncertainties for equity and inclusive development in cities. *Cities*, **60**, 378-387, doi:https://doi.org/10.1016/j.cities.2016.10.016.

Cinner, J. E. et al., 2018: Building adaptive capacity to climate change in tropical coastal communities. *Nature Climate Change*, **8** (2), 117-123, doi:10.1038/s41558-017-0065-x.

Condie, H. M., A. Grant and T. L. Catchpole, 2014: Incentivising selective fishing under a policy to ban discards; lessons from European and global fisheries. *Marine Policy*, **45** (C), 287-292.

Cools, J., D. Innocenti and S. O'Brien, 2016: Lessons from flood early warning systems. *Environmental Science & Policy*, **58**, 117-122, doi:https://doi.org/10.1016/j.envsci.2016.01.006.

Cooper, J. A. G., M. C. O'Connor and S. McIvor, 2020: Coastal defences versus coastal ecosystems: A regional appraisal. *Marine Policy*, **111**, 102332, doi:https://doi.org/10.1016/j.marpol.2016.02.021.

Cooper, J. A. G. and J. Pile, 2014: The adaptation-resistance spectrum: A classification of contemporary adaptation approaches to climate-related coastal change. *Ocean & Coastal Management*, **94**, 90-98, doi:https://doi.org/10.1016/j.ocecoaman.2013.09.006.

Cornwall, W., 2021: Unleashing Big Muddy. *Science*, **372** (6540), 334-337, doi:10.1126/science.abj1040.

Cosens, B. A. et al., 2017: The role of law in adaptive governance. *Ecology and Society*, **22** (1), doi:10.5751/ES-08731-220130.

Craig, R. K. et al., 2017: Balancing stability and flexibility in adaptive governance: an analysis of tools available in U.S. environmental law. *Ecology and Society*, **22** (2), doi:10.5751/ES-08983-220203.

Crescenzi, R. and A. Rodríguez-Pose, 2017: The Geography of Innovation in China and India. *International Journal of Urban and Regional Research*, **41** (6), 1010-1027, doi:https://doi.org/10.1111/1468-2427.12554.

Das, S. and J. R. Vincent, 2009: Mangroves protected villages and reduced death toll during Indian super cyclone. *Proceedings of the National Academy of Sciences*, **106** (18), 7357-7360, doi:10.1073/pnas.0810440106.

Davis, K. F., A. Bhattachan, P. D'Odorico and S. Suweis, 2018: A universal model for predicting human migration under climate change: examining future sea level rise in Bangladesh. *Environmental Research Letters*, **13** (6), doi:10.1088/1748-9326/aac4d4.

Day, J. W. et al., 2016: Large infrequently operated river diversions for Mississippi delta restoration. *Estuarine, Coastal and Shelf Science*, **183**, 292-303, doi:https://doi.org/10.1016/j.ecss.2016.05.001.

de Ruig, L. T. et al., 2019: An economic evaluation of adaptation pathways in coastal mega cities: An illustration for Los Angeles. *Science of The Total Environment*, **678**, 647-659, doi:https://doi.org/10.1016/j.scitotenv.2019.04.308.

de Schipper, M. A. et al., 2021: Beach nourishment has complex implications for the future of sandy shores. *Nature Reviews Earth & Environment*, **2** (1), 70-84, doi:10.1038/s43017-020-00109-9.

DeCaro, D. A. et al., 2017: Legal and institutional foundations of adaptive environmental governance. *Ecology and Society*, **22** (1), doi:10.5751/ES-09036-220132.

Dedekorkut-Howes, A., E. Torabi and M. Howes, 2020: When the tide gets high: a review of adaptive responses to sea level rise and coastal flooding. *Journal of Environmental Planning and Management*, **63** (12), 2102-2143, doi:10.1080/09640568.2019.1708709.

del Valle, A., M. Eriksson, O. A. Ishizawa and J. J. Miranda, 2020: Mangroves protect coastal economic activity from hurricanes. *Proceedings of the National Academy of Sciences*, **117** (1), 265-270, doi:10.1073/pnas.1911617116.

Depietri, Y. and T. McPhearson, 2017: Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction. In: Nature-Based Solutions to Climate Change Adaptation in

Urban Areas: Linkages between Science, Policy and Practice [Kabisch, N., H. Korn, J. Stadler and A. Bonn (eds.)]. Springer International Publishing, Cham, 91-109.
Di Baldassarre, G. et al., 2018: Hess Opinions: An interdisciplinary research agenda to explore the unintended consequences of structural flood protection. *Hydrol. Earth Syst. Sci.*, **22** (11), 5629-5637, doi:10.5194/hess-22-5629-2018.
Di Baldassarre, G. et al., 2015: Debates—Perspectives on socio-hydrology: Capturing feedbacks between physical and social processes. *Water Resources Research*, **51** (6), 4770-4781, doi:https://doi.org/10.1002/2014WR016416.
Di Giulio, G. M. et al., 2019: Bridging the gap between will and action on climate change adaptation in large cities in Brazil. *Regional Environmental Change*, **19** (8), 2491-2502, doi:10.1007/s10113-019-01570-z.
Doberstein, B., J. Fitzgibbons and C. Mitchell, 2019: Protect, accommodate, retreat or avoid (PARA): Canadian community options for flood disaster risk reduction and flood resilience. *Natural Hazards*, **98** (1), 31-50, doi:10.1007/s11069-018-3529-z.
Doberstein, B., A. Tadgell and A. Rutledge, 2020: Managed retreat for climate change adaptation in coastal megacities: A comparison of policy and practice in Manila and Vancouver. *Journal of Environmental Management*, **253**, 109753, doi:https://doi.org/10.1016/j.jenvman.2019.109753.
Donchyts, G. et al., 2016: Earth's surface water change over the past 30 years. *Nature Climate Change*, **6**, 810-813, doi:10.1038/nclimate3111.
Donner, S. D., M. Kandlikar and S. Webber, 2016: Measuring and tracking the flow of climate change adaptation aid to the developing world. *Environmental Research Letters*, **11** (5), 054006, doi:10.1088/1748-9326/11/5/054006.
Donner, S. D. 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.
Druzhinin, A., A. Mikhaylov and A. Lialina, 2021: Coastal Regions of Russia: Migration Attractiveness and Innovation Performance. *Quaestiones Geographicae*, **40** (2), 5-18, doi:doi:10.2478/quageo-2021-0019.
Du, S. et al., 2020: Hard or soft flood adaptation? Advantages of a hybrid strategy for Shanghai. *Global Environmental Change*, **61**, 102037, doi:https://doi.org/10.1016/j.gloenvcha.2020.102037.
Dulal, H. B., 2019: Cities in Asia: how are they adapting to climate change? *Journal of Environmental Studies and Sciences*, **9** (1), 13-24.
Duncan, C. et al., 2018: Satellite remote sensing to monitor mangrove forest resilience and resistance to sea level rise. *Methods in Ecology and Evolution*, **9** (8), 1837-1852, doi:https://doi.org/10.1111/2041-210X.12923.
Duy, P. N. et al., 2018: Urban Resilience to Floods in Coastal Cities: Challenges and Opportunities for Ho Chi Minh City and Other Emerging Cities in Southeast Asia. *Journal of Urban Planning and Development*, **144** (1), 05017018, doi:doi:10.1061/(ASCE)UP.1943-5444.0000419.
Edmonds, D. A., R. L. Caldwell, E. S. Brondizio and S. M. O. Siani, 2020: Coastal flooding will disproportionately impact people on river deltas. *Nature Communications*, **11** (1), 4741, doi:10.1038/s41467-020-18531-4.
Eilander, D. et al., 2020: The effect of surge on riverine flood hazard and impact in deltas globally. *Environmental Research Letters*, **15** (10), 104007, doi:10.1088/1748-9326/ab8ca6.
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:https://doi.org/10.1016/j.ocecoaman.2018.10.031.
Esteban, M., M. Onuki, I. Ikeda and T. Akiyama, 2015: Chapter 29 - Reconstruction Following the 2011 Tohoku Earthquake Tsunami: Case Study of Otsuchi Town in Iwate Prefecture, Japan. In: Handbook of Coastal Disaster Mitigation for Engineers and Planners [Esteban, M., H. Takagi and T. Shibayama (eds.)]. Butterworth-Heinemann, Boston, 615-631.
Esteban, M. et al., 2020a: Adaptation to sea level rise: Learning from present examples of land subsidence. *Ocean & Coastal Management*, **189**, 104852, doi:https://doi.org/10.1016/j.ocecoaman.2019.104852.
Esteban, M. et al., 2017: Awareness of coastal floods in impoverished subsiding coastal communities in Jakarta: Tsunamis, typhoon storm surges and dyke-induced tsunamis. *International Journal of Disaster Risk Reduction*, **23**, 70-79, doi:https://doi.org/10.1016/j.ijdrr.2017.04.007.
Esteban, M. et al., 2020b: Adapting ports to sea-level rise: empirical lessons based on land subsidence in Indonesia and Japan. *Maritime Policy & Management*, **47** (7), 937-952, doi:10.1080/03088839.2019.1634845.
Estrada, F., W. J. W. Botzen and R. S. J. Tol, 2017: A global economic assessment of city policies to reduce climate change impacts. *Nature Climate Change*, **7** (6), 403-406, doi:10.1038/nclimate3301.
Evans, A. J. et al., 2017: Stakeholder priorities for multi-functional coastal defence developments and steps to effective implementation. *Marine Policy*, **75**, 143-155, doi:https://doi.org/10.1016/j.marpol.2016.10.006.
Farbotko, C. et al., 2020: Relocation planning must address voluntary immobility. *Nature Climate Change*, **10** (8), 702-704, doi:10.1038/s41558-020-0829-6.
Fayombo, O. O., 2020: Discursive constructions underlie and exacerbate the vulnerability of informal urban communities to the impacts of climate change. *Climate and Development*, 1-13, doi:10.1080/17565529.2020.1765133.
Feagin, R. A. et al., 2019: The role of beach and sand dune vegetation in mediating wave run up erosion. *Estuarine, Coastal and Shelf Science*, **219**, 97-106, doi:https://doi.org/10.1016/j.ecss.2019.01.018.
Ferguson, B. C. et al., 2013: The enabling institutional context for integrated water management: Lessons from Melbourne. *Water Research*, **47** (20), 7300-7314, doi:https://doi.org/10.1016/j.watres.2013.09.045.

Ferrario, F. et al., 2014: The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. *Nature Communications*, **5**, 3794.

Fink, J. H., 2019: Contrasting governance learning processes of climate-leading and -lagging cities: Portland, Oregon, and Phoenix, Arizona, USA. *Journal of Environmental Policy & Planning*, **21** (1), 16-29, doi:10.1080/1523908X.2018.1487280.

Fisher, K. and R. Goodliffe, 2019: Adaptive Coastal Management at Three Sites in East Anglia. In: *Coastal Management 2019*, [Hardiman, N. and I. o. C. Engineers (eds.)], 245-258, doi:10.1680/cm.65147.245.

Ford, J. D., G. McDowell and T. Pearce, 2015: The adaptation challenge in the Arctic. *Nature Climate Change*, **5**, 1046, doi:10.1038/nclimate2723
https://www.nature.com/articles/nclimate2723#supplementary-information.

Fox-Rogers, L. et al., 2016: Is there really "nothing you can do"? Pathways to enhanced flood-risk preparedness. *Journal of Hydrology*, **543**, 330-343, doi:https://doi.org/10.1016/j.jhydrol.2016.10.009.

Frederiksen, M., 2014: Trust in the face of uncertainty: a qualitative study of intersubjective trust and risk. *International Review of Sociology*, **24** (1), 130-144, doi:10.1080/03906701.2014.894335.

Fu, X., 2020: Measuring local sea-level rise adaptation and adaptive capacity: A national survey in the United States. *Cities*, **102**, 102717, doi:https://doi.org/10.1016/j.cities.2020.102717.

Garmestani, A. S. and M. H. Benson, 2013: A Framework for Resilience-based Governance of Social-Ecological Systems. *Ecology and Society*, **18** (1), doi:10.5751/ES-05180-180109.

Garschagen, M., 2015: Risky Change? Vietnam's Urban Flood Risk Governance between Climate Dynamics and Transformation. *Pacific Affairs*, **88** (3), 599-621, doi:10.5509/2015883599.

Garschagen, M., G. A. K. Surtiari and M. Harb, 2018: Is Jakarta's new flood risk reduction strategy transformational? *Sustainability*, **10** (8), 2934, doi:https://doi.org/10.3390/su10082934.

Ghanbari, M. et al., 2021: Climate Change and Changes in Compound Coastal-Riverine Flooding Hazard Along the U.S. Coasts. *Earth's Future*, **9** (5), e2021EF002055, doi:https://doi.org/10.1029/2021EF002055.

Ghosh, M. K., L. Kumar and P. Kibet Langat, 2019: Geospatial modelling of the inundation levels in the Sundarbans mangrove forests due to the impact of sea level rise and identification of affected species and regions. *Geomatics, Natural Hazards and Risk*, **10** (1), 1028-1046, doi:10.1080/19475705.2018.1564373.

Gibbs, M. T., 2015: Pitfalls in developing coastal climate adaptation responses. *Climate Risk Management*, **8**, 1-8, doi:https://doi.org/10.1016/j.crm.2015.05.001.

Gibbs, M. T., 2016: Why is coastal retreat so hard to implement? Understanding the political risk of coastal adaptation pathways. *Ocean & Coastal Management*, **130**, 107-114, doi:https://doi.org/10.1016/j.ocecoaman.2016.06.002.

Gibbs, M. T., 2020: The two-speed coastal climate adaptation economy in Australia. *Ocean & Coastal Management*, **190**, 105150, doi:https://doi.org/10.1016/j.ocecoaman.2020.105150.

Glavovic, B. C., 2013: Coastal innovation paradox. *Sustainability*, **5** (3), 912-933, doi:https://doi.org/10.3390/su5030912.

Godfroy, M., V. Vuik, E. van Berchum and B. Jonkman, 2019: Quantifying Wave Attenuation by Nature-based Solutions in the Galveston Bay. In: *Coastal Structures 2019*, 1008-1019, doi:https://doi.org/10.18451/978-3-939230-64-9_101.

Goh, K., 2019: Urban Waterscapes: The Hydro-Politics of Flooding in a Sinking City. *International Journal of Urban and Regional Research*, **43** (2), 250-272, doi:10.1111/1468-2427.12756.

Gould, K. A. and T. L. Lewis, 2018: From Green Gentrification to Resilience Gentrification: An Example from Brooklyn1. *City & Community*, **17** (1), 12-15, doi:10.1111/cico.12283.

Gralepois, M. et al., 2016: Is flood defense changing in nature? Shifts in the flood defense strategy in six European countries. *Ecology and Society*, **21** (4).

Green, O. O. et al., 2015: Barriers and bridges to the integration of social–ecological resilience and law. *Frontiers in Ecology and the Environment*, **13** (6), 332-337, doi:https://doi.org/10.1890/140294.

Griggs, G. and K. Patsch, 2019: The Protection/Hardening of California's Coast: Times Are Changing. *Journal of Coastal Research*, **35** (5), 1051-1061, doi:10.2112/jcoastres-d-19a-00007.1.

Haasnoot, M. et al., 2020: Defining the solution space to accelerate climate change adaptation. *Regional Environmental Change*, **20** (2), 37, doi:10.1007/s10113-020-01623-8.

Haasnoot, M. et al., 2019: Generic adaptation pathways for coastal archetypes under uncertain sea-level rise. *Environmental Research Communications*, doi:10.1088/2515-7620/ab1871.

Haasnoot, M., J. Lawrence and A. K. Magnan, 2021a: Pathways to coastal retreat. *Science*, **372** (6548), 1287-1290, doi:10.1126/science.abi6594.

Haasnoot, M. et al., 2021b: Long-term sea-level rise necessitates a commitment to adaptation: A first order assessment. *Climate Risk Management*, **34**, doi:https://doi.org/10.1016/j.crm.2021.100355.

Hall, J. W., H. Harvey and L. J. Manning, 2019: Adaptation thresholds and pathways for tidal flood risk management in London. *Climate Risk Management*, **24**, 42-58, doi:https://doi.org/10.1016/j.crm.2019.04.001.

Hallegatte, S., A. Vogt-Schilb, M. Bangalore and J. Rozenberg, 2017: *Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters*. Climate Change and Development Series, World Bank, Washington, DC.

Hanna, C., I. White and B. Glavovic, 2019: Managed Retreat in Practice: Mechanisms and Challenges for Implementation. Oxford University Press, doi:10.1093/acrefore/9780199389407.013.350.

Hanna, C., I. White and B. Glavovic, 2020: The Uncertainty Contagion: Revealing the Interrelated, Cascading Uncertainties of Managed Retreat. *Sustainability*, **12** (2), 736, doi:https://doi.org/10.3390/su12020736.
Hanson, S. E. and R. J. Nicholls, 2020: Demand for Ports to 2050: Climate Policy, Growing Trade and the Impacts of Sea-Level Rise. *Earth's Future*, **8** (8), e2020EF001543, doi:https://doi.org/10.1029/2020EF001543.
Haraguchi, M. and S. Kim, 2016: Critical infrastructure interdependence in New York City during Hurricane Sandy. *International Journal of Disaster Resilience in the Built Environment*, **7** (2), 133-143, doi:10.1108/IJDRBE-03-2015-0015.
Harris, B. D. et al., 2021: Establishment of soil strength in a nourished wetland using thin layer placement of dredged sediment. *PLoS One*, **16** (5), e0251420, doi:10.1371/journal.pone.0251420.
Harris, L. M., E. K. Chu and G. Ziervogel, 2018: Negotiated resilience. *Resilience*, **6** (3), 196-214, doi:10.1080/21693293.2017.1353196.
Hauer, M. E., 2017: Migration induced by sea-level rise could reshape the US population landscape. *Nature Climate Change*, **7**, 321, doi:10.1038/nclimate3271
https://www.nature.com/articles/nclimate3271#supplementary-information.
Hauer, M. E. et al., 2020: Sea-level rise and human migration. *Nature Reviews Earth & Environment*, **1** (1), 28-39, doi:10.1038/s43017-019-0002-9.
He, Q. and B. R. Silliman, 2019: Climate Change, Human Impacts, and Coastal Ecosystems in the Anthropocene. *Current Biology*, **29** (19), R1021-R1035, doi:https://doi.org/10.1016/j.cub.2019.08.042.
He, X., 2018: Legal and Policy Pathways of Climate Change Adaptation: Comparative Analysis of the Adaptation Practices in the United States, Australia and China. *Transnational Environmental Law*, **7** (2), 347-373, doi:10.1017/S2047102518000092.
Herrick, C. N., 2018: Self-Identity and Sense of Place: Some Thoughts Regarding Climate Change Adaptation Policy Formulation. *Environmental Values*, **27** (1), 81-102, doi:10.3197/096327118X15144698637531.
Hiatt, M. et al., 2019: Drivers and impacts of water level fluctuations in the Mississippi River delta: Implications for delta restoration. *Estuarine, Coastal and Shelf Science*, **224**, 117-137, doi:https://doi.org/10.1016/j.ecss.2019.04.020.
Hindsley, P. and D. Yoskowitz, 2020: Global change—Local values: Assessing tradeoffs for coastal ecosystem services in the face of sea level rise. *Global Environmental Change*, **61**, 102039, doi:https://doi.org/10.1016/j.gloenvcha.2020.102039.
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.
Hinkel, J. et al., 2014: Coastal flood damage and adaptation costs under 21st century sea-level rise. *Proceedings of the National Academy of Sciences*, **111** (9), 3292-3297.
Hino, M., C. B. Field and K. J. Mach, 2017: Managed retreat as a response to natural hazard risk. *Nature Climate Change*, **7** (5), 364-370, doi:10.1038/nclimate3252.
Hissel, F. et al., 2014: Early warning and mass evacuation in coastal cities. *Coastal Engineering*, **87**, 193-204, doi:https://doi.org/10.1016/j.coastaleng.2013.11.015.
Hiwasaki, L., E. Luna, Syamsidik and J. A. Marçal, 2015: Local and indigenous knowledge on climate-related hazards of coastal and small island communities in Southeast Asia. *Climatic Change*, **128** (1), 35-56, doi:10.1007/s10584-014-1288-8.
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:https://doi.org/10.1016/j.ijdrr.2014.07.007.
Hochard, J. P., S. Hamilton and E. B. Barbier, 2019: Mangroves shelter coastal economic activity from cyclones. *Proceedings of the National Academy of Sciences*, **116** (25), 12232-12237, doi:10.1073/pnas.1820067116.
Hoegh-Guldberg, O. et al., 2018: Impacts of 1.5ºC 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. Péan, 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.)]. In Press.
Hoffmann, R. et al., 2020: A meta-analysis of country-level studies on environmental change and migration. *Nature Climate Change*, **10** (10), 904-912, doi:10.1038/s41558-020-0898-6.
Hölscher, K., N. Frantzeskaki, T. McPhearson and D. Loorbach, 2019: Tales of transforming cities: Transformative climate governance capacities in New York City, U.S. and Rotterdam, Netherlands. *Journal of Environmental Management*, **231**, 843-857, doi:https://doi.org/10.1016/j.jenvman.2018.10.043.
Hooijer, A. and R. Vernimmen, 2021: Global LiDAR land elevation data reveal greatest sea-level rise vulnerability in the tropics. *Nature Communications*, **12** (1), 3592, doi:10.1038/s41467-021-23810-9.
Hu, H. et al., 2019: Synthesized trade-off analysis of flood control solutions under future deep uncertainty: An application to the central business district of Shanghai. *Water Research*, **166**, 115067, doi:https://doi.org/10.1016/j.watres.2019.115067.

IPCC, 2019: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H. O., D. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanka, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)]. In press.
Izaguirre, C. et al., 2021: Climate change risk to global port operations. *Nature Climate Change*, **11** (1), 14-20, doi:10.1038/s41558-020-00937-z.
Jain, G., C. Singh, K. Coelho and T. Malladi, 2017: *Long-term implications of humanitarian responses: the case of Chennai*. IIED Working Paper, IIED, London.
Jain, G., C. Singh and T. Malladi, 2021: (Re)creating disasters
a case of post-disaster resettlements in Chennai. In: Rethinking Urban Risk and Resettlement in the Global South [Jain, G., C. Johnson and A. Lavell (eds.)]. UCL Press, 269-289.
Jamero, M. L., M. Onuki, M. Esteban and N. Tan, 2018: Community-based adaptation in low-lying islands in the Philippines: challenges and lessons learned. *Regional Environmental Change*, **18** (8), 2249-2260, doi:10.1007/s10113-018-1332-8.
James, R. K. et al., 2020: Tropical Biogeomorphic Seagrass Landscapes for Coastal Protection: Persistence and Wave Attenuation During Major Storms Events. *Ecosystems*, doi:10.1007/s10021-020-00519-2.
Javeline, D., T. Kijewski-Correa and A. Chesler, 2019: Does it matter if you "believe" in climate change? Not for coastal home vulnerability. *Climatic Change*, **155** (4), 511-532, doi:10.1007/s10584-019-02513-7.
Jeuken, A., M. Haasnoot, T. Reeder and P. Ward, 2014: Lessons learnt from adaptation planning in four deltas and coastal cities. *Journal of Water and Climate Change*, **6** (4), 711-728, doi:10.2166/wcc.2014.141.
Johnson, C., G. Jain and A. Lavell, Eds., 2021: Rethinking Urban Risk and Resettlement in the Global South. UCL Press,
Jones, H. P. et al., 2020: Global hotspots for coastal ecosystem-based adaptation. *PLoS One*, **15** (5), e0233005, doi:10.1371/journal.pone.0233005.
Jongman, B., 2018: Effective adaptation to rising flood risk. *Nature Communications*, **9** (1), 1986, doi:10.1038/s41467-018-04396-1.
Kabat, P. et al., 2009: Dutch coasts in transition. *Nature Geoscience*, **2** (7), 450.
Karlsson, M. and G. K. Hovelsrud, 2015: Local collective action: Adaptation to coastal erosion in the Monkey River Village, Belize. *Global Environmental Change*, **32**, 96-107, doi:https://doi.org/10.1016/j.gloenvcha.2015.03.002.
Kay, R. and J. Alder, 2017: *Coastal planning and management*. CRC Press.
Keenan, J. M., T. Hill and A. Gumber, 2018: Climate gentrification: from theory to empiricism in Miami-Dade County, Florida. *Environmental Research Letters*, **13** (5), 054001, doi:10.1088/1748-9326/aabb32.
Kench, P. S. 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.
Kettle, N. P. and K. Dow, 2016: The Role of Perceived Risk, Uncertainty, and Trust on Coastal Climate Change Adaptation Planning. *Environment and Behavior*, **48** (4), 579-606, doi:10.1177/0013916514551049.
Kirezci, E. et al., 2020: Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st Century. *Scientific Reports*, **10** (1), 11629, doi:10.1038/s41598-020-67736-6.
Kirwan, M. L. et al., 2016: Overestimation of marsh vulnerability to sea level rise. *Nature Climate Change*, **6**, 253, doi:10.1038/nclimate2909.
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.
Kleinhans, M. G., H. J. T. Weerts and K. M. Cohen, 2010: Avulsion in action: Reconstruction and modelling sedimentation pace and upstream flood water levels following a Medieval tidal-river diversion catastrophe (Biesbosch, The Netherlands, 1421–1750AD). *Geomorphology*, **118** (1), 65-79, doi:https://doi.org/10.1016/j.geomorph.2009.12.009.
Klepp, S., 2018: Framing Climate Change Adaptation from a Pacific Island Perspective–The Anthropology of Emerging Legal Orders. *Sociologus*, **68** (2), 149-170, doi:https://doi.org/10.3790/soc.68.2.149.
Kok, S. et al., 2021: The potential of nature-based flood defences to leverage public investment in coastal adaptation: Cases from the Netherlands, Indonesia and Georgia. *Ecological Economics*, **179**, 106828, doi:https://doi.org/10.1016/j.ecolecon.2020.106828.
Koks, E. E. et al., 2019: A global multi-hazard risk analysis of road and railway infrastructure assets. *Nature Communications*, **10** (1), 2677, doi:10.1038/s41467-019-10442-3.
Kool, R., J. Lawrence, M. Drews and R. Bell, 2020: Preparing for Sea-Level Rise through Adaptive Managed Retreat of a New Zealand Stormwater and Wastewater Network. *Infrastructures*, **5** (11), doi:https://doi.org/10.3390/infrastructures5110092.
Krause, G. et al., 2020: Visualizing the social in aquaculture: How social dimension components illustrate the effects of aquaculture across geographic scales. *Marine Policy*, **118**, 103985, doi:https://doi.org/10.1016/j.marpol.2020.103985.
Kulp, S. A. and B. H. Strauss, 2019: New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. *Nature Communications*, **10** (1), 4844, doi:10.1038/s41467-019-12808-z.
Kumar, P. et al., 2021: Nature-based solutions efficiency evaluation against natural hazards: Modelling methods, advantages and limitations. *Science of The Total Environment*, **784**, 147058, doi:https://doi.org/10.1016/j.scitotenv.2021.147058.

Lassa, J. A. and E. Nugraha, 2014: From shared learning to shared action in building resilience in the city of Bandar Lampung, Indonesia. *Environment and Urbanization*, **27** (1), 161-180, doi:10.1177/0956247814552233.
Lau, J. D., C. C. Hicks, G. G. Gurney and J. E. Cinner, 2019: What matters to whom and why? Understanding the importance of coastal ecosystem services in developing coastal communities. *Ecosystem Services*, **35**, 219-230, doi:https://doi.org/10.1016/j.ecoser.2018.12.012.
Laurice Jamero, M. 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.
Lawrence, J. et al., 2020: Implementing Pre-Emptive Managed Retreat: Constraints and Novel Insights. *Current Climate Change Reports*, **6** (3), 66-80, doi:10.1007/s40641-020-00161-z.
Le Cozannet, G. et al., 2017: Sea level change and coastal climate services: The way forward. *Journal of Marine Science and Engineering*, **5** (4), 49.
Le, T. D. N., 2020: Climate change adaptation in coastal cities of developing countries: characterizing types of vulnerability and adaptation options. *Mitigation and adaptation strategies for global change*, **25** (5), 739-761, doi:10.1007/s11027-019-09888-z.
Leal Filho, W. et al., 2018: Fostering coastal resilience to climate change vulnerability in Bangladesh, Brazil, Cameroon and Uruguay: a cross-country comparison. *Mitigation and adaptation strategies for global change*, **23** (4), 579-602, doi:10.1007/s11027-017-9750-3.
Lehmann, M. et al., 2021: The way forward: Supporting climate adaptation in coastal towns and small cities. *Ocean & Coastal Management*, **212**, 105785, doi:https://doi.org/10.1016/j.ocecoaman.2021.105785.
Lendering, K. T., S. N. Jonkman, M. van Ledden and J. K. Vrijling, 2020: Defend or raise? Optimising flood risk reduction strategies. *Journal of Flood Risk Management*, **13** (S1), e12553, doi:10.1111/jfr3.12553.
León-Mateos, F., A. Sartal, L. López-Manuel and M. A. Quintás, 2021: Adapting our sea ports to the challenges of climate change: Development and validation of a Port Resilience Index. *Marine Policy*, **130**, 104573, doi:https://doi.org/10.1016/j.marpol.2021.104573.
Li, X. et al., 2014: The impact of the change in vegetation structure on the ecological functions of salt marshes: the example of the Yangtze estuary. *Regional Environmental Change*, **14** (2), 623-632, doi:10.1007/s10113-013-0520-9.
Lincke, D. and J. Hinkel, 2018: Economically robust protection against 21st century sea-level rise. *Global Environmental Change*, **51**, 67-73, doi:10.1016/j.gloenvcha.2018.05.003.
Lincke, D. and J. Hinkel, 2021: Coastal Migration due to 21st Century Sea-Level Rise. *Earth's Future*, **9** (5), e2020EF001965, doi:https://doi.org/10.1029/2020EF001965.
Lincke, D. et al., 2020: The effectiveness of setback zones for adapting to sea-level rise in Croatia. *Regional Environmental Change*, **20** (2), 46, doi:10.1007/s10113-020-01628-3.
Long, N., P. Cornut and V. Kolb, 2021: Strategies for adapting to hazards and environmental inequalities in coastal urban areas: what kind of resilience for these territories? *Nat. Hazards Earth Syst. Sci.*, **21** (3), 1087-1100, doi:10.5194/nhess-21-1087-2021.
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), 1940004, doi:10.1142/s2345737619400049.
Lu, Y. et al., 2018: Major threats of pollution and climate change to global coastal ecosystems and enhanced management for sustainability. *Environmental Pollution*, **239**, 670-680, doi:https://doi.org/10.1016/j.envpol.2018.04.016.
Luijendijk, A. et al., 2018: The State of the World's Beaches. *Sci Rep*, **8** (1), 6641, doi:10.1038/s41598-018-24630-6.
Mach, K. J. and A. R. Siders, 2021: Reframing strategic, managed retreat for transformative climate adaptation. *Science*, **372** (6548), 1294-1299, doi:10.1126/science.abh1894.
Macreadie, P. I. et al., 2017: Can we manage coastal ecosystems to sequester more blue carbon? *Frontiers in Ecology and the Environment*, **15** (4), 206-213, doi:10.1002/fee.1484.
Magnan, A. K. and V. K. E. Duvat, 2020: Towards adaptation pathways for atoll islands. Insights from the Maldives. *Regional Environmental Change*, **20** (4), 119, doi:10.1007/s10113-020-01691-w.
Magnan, A. K. et al., 2019: Integrative Cross-Chapter Box on Low-lying Islands and Coasts. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)]. In Press.
Marchau, V. A. W. J., W. E. Walker, P. J. T. M. Bloemen and S. W. Popper, 2019: *Decision Making under Deep Uncertainty: From Theory to Practice*. Decision Making under Deep Uncertainty: From Theory to Practice, Springer International Publishing, Cham, 1-405 pp.
Mariano, C., M. Marino, G. Pisacane and G. Sannino, 2021: Sea Level Rise and Coastal Impacts: Innovation and Improvement of the Local Urban Plan for a Climate-Proof Adaptation Strategy. *Sustainability*, **13** (3), 1565.
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:https://doi.org/10.1016/j.cosust.2021.05.001.
Masselink, G., E. Beetham and P. Kench, 2020: Coral reef islands can accrete vertically in response to sea level rise. *Science Advances*, **6** (24), eaay3656, doi:10.1126/sciadv.aay3656.

McGranahan, G., D. Balk and B. Anderson, 2007: The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization*, **19** (1), 17-37, doi:10.1177/0956247807076960.
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.
McLean, R. and P. Kench, 2015: Destruction or persistence of coral atoll islands in the face of 20th and 21st century sea-level rise? *WIREs Climate Change*, **6** (5), 445-463, doi:10.1002/wcc.350.
McLeman, R. et al., 2021: Conceptual framing to link climate risk assessments and climate-migration scholarship. *Climatic Change*, **165** (1), 24, doi:10.1007/s10584-021-03056-6.
McMichael, C., S. Dasgupta, S. Ayeb-Karlsson and I. Kelman, 2020: A review of estimating population exposure to sea-level rise and the relevance for migration. *Environmental Research Letters*, doi:10.1088/1748-9326/abb398.
McNamara, D. E., S. Gopalakrishnan, M. D. Smith and A. B. Murray, 2015: Climate Adaptation and Policy-Induced Inflation of Coastal Property Value. *PLoS One*, **10** (3), e0121278, doi:10.1371/journal.pone.0121278.
Meerow, S., 2017: Double exposure, infrastructure planning, and urban climate resilience in coastal megacities: A case study of Manila. *Environment and Planning A: Economy and Space*, **49** (11), 2649-2672, doi:10.1177/0308518x17723630.
Mendenhall, E. et al., 2020: Climate change increases the risk of fisheries conflict. *Marine Policy*, **117**, 103954, doi:https://doi.org/10.1016/j.marpol.2020.103954.
Menéndez, P. et al., 2020: The Global Flood Protection Benefits of Mangroves. *Scientific Reports*, **10** (1), 4404, doi:10.1038/s41598-020-61136-6.
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.
Merkens, J.-L. et al., 2018: Regionalisation of population growth projections in coastal exposure analysis. *Climatic Change*, **151** (3), 413-426, doi:10.1007/s10584-018-2334-8.
Mohamed Shaffril, H. A. et al., 2020: Systematic literature review on adaptation towards climate change impacts among indigenous people in the Asia Pacific regions. *Journal of Cleaner Production*, **258**, 120595, doi:https://doi.org/10.1016/j.jclepro.2020.120595.
Möller, I. et al., 2014: Wave attenuation over coastal salt marshes under storm surge conditions. *Nature Geoscience*, **7**, 727, doi:10.1038/ngeo2251
https://www.nature.com/articles/ngeo2251#supplementary-information.
Morris, R. L., A. Boxshall and S. E. Swearer, 2020: Climate-resilient coasts require diverse defence solutions. *Nature Climate Change*, **10** (6), 485-487, doi:10.1038/s41558-020-0798-9.
Morris, R. L. et al., 2019: Kelp beds as coastal protection: wave attenuation of Ecklonia radiata in a shallow coastal bay. *Annals of Botany*, **125** (2), 235-246, doi:10.1093/aob/mcz127.
Morris, R. L., T. M. Konlechner, M. Ghisalberti and Stephen E. 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.
Mortreux, C. et al., 2018: Political economy of planned relocation: A model of action and inaction in government responses. *Global Environmental Change*, **50**, 123-132, doi:https://doi.org/10.1016/j.gloenvcha.2018.03.008.
Muis, S. et al., 2016: A global reanalysis of storm surges and extreme sea levels. *Nature Communications*, **7** (1), 11969, doi:10.1038/ncomms11969.
Nagy, G. J. et al., 2019: Climate vulnerability, impacts and adaptation in Central and South America coastal areas. *Regional Studies in Marine Science*, **29**, 100683, doi:https://doi.org/10.1016/j.rsma.2019.100683.
Nakashima, D., J. T. Rubis and I. Krupnik, 2018: Indigenous Knowledge for Climate Change Assessment and Adaptation: Introduction. In: Indigenous Knowledge for Climate Change Assessment and Adaptation [Nakashima, D., I. Krupnik and J. T. Rubis (eds.)]. Cambridge University Press, Cambridge, 1-20.
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., 2017: The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA. *Scientific Reports*, **7** (1), 9463, doi:10.1038/s41598-017-09269-z.
Ndebele-Murisa, M. R. et al., 2020: City to city learning and knowledge exchange for climate resilience in southern Africa. *PLoS One*, **15** (1), e0227915, doi:10.1371/journal.pone.0227915.
Neef, A. et al., 2018: Climate adaptation strategies in Fiji: The role of social norms and cultural values. *World Development*, **107**, 125-137, doi:https://doi.org/10.1016/j.worlddev.2018.02.029.
Neise, T. and J. Revilla Diez, 2019: Adapt, move or surrender? Manufacturing firms' routines and dynamic capabilities on flood risk reduction in coastal cities of Indonesia. *International Journal of Disaster Risk Reduction*, **33**, 332-342, doi:https://doi.org/10.1016/j.ijdrr.2018.10.018.
Nesshöver, C. et al., 2017: The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Science of The Total Environment*, **579**, 1215-1227, doi:https://doi.org/10.1016/j.scitotenv.2016.11.106.
Neumann, B., A. T. Vafeidis, J. Zimmermann and R. J. Nicholls, 2015: Future coastal population growth and exposure to sea-level rise and coastal flooding--a global assessment. *PLoS One*, **10** (3), e0118571, doi:10.1371/journal.pone.0118571.

Nicholls, R. J. et al., 2018: Stabilization of global temperature at 1.5C and 2.0C: implications for coastal areas. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **376** (2119), 20160448, doi:doi:10.1098/rsta.2016.0448.
Nicholls, R. J., R. J. Dawson and S. A. Day, 2015: *Broad Scale Coastal Simulation: New Techniques to Understand and Manage Shorelines in the Third Millennium*. Broad Scale Coastal Simulation: New Techniques to Understand and Manage Shorelines in the Third Millennium, 1-398 pp.
Nicholls, R. J. et al., 2021: A global analysis of subsidence, relative sea-level change and coastal flood exposure. *Nature Climate Change*, **11** (4), 338-342, doi:10.1038/s41558-021-00993-z.
Nicholls, R. J. and C. Small, 2002: Improved estimates of coastal population and exposure to hazards released. *Eos, Transactions American Geophysical Union*, **83** (28), 301-305, doi:https://doi.org/10.1029/2002EO000216.
NIES and ISME. Tropical Coastal Ecosystems Portal (TroCEP). [Available at, accessed 5/11/2020]
Nilubon, P., W. Veerbeek and C. Zevenbergen, 2016: Amphibious Architecture and Design: A Catalyst of Opportunistic Adaptation? – Case Study Bangkok. *Procedia - Social and Behavioral Sciences*, **216**, 470-480, doi:https://doi.org/10.1016/j.sbspro.2015.12.063.
Nittrouer, J. A. et al., 2012: Mitigating land loss in coastal Louisiana by controlled diversion of Mississippi River sand. *Nature Geoscience*, **5** (8), 534-537, doi:10.1038/ngeo1525.
Nunn, P. D., J. Runman, M. Falanruw and R. Kumar, 2017: 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.
NYCEDC, 2019: *Lower Manhattan Climate Resilience Study*. New York City Economic Development Corporation [Available at: https://edc.nyc/project/lower-manhattan-coastal-resiliency].
O'Donnell, T., 2021: Coastal Lawscape: A framework for understanding the complexities of climate change adaptation. *Marine Policy*, **129**, 104532, doi:https://doi.org/10.1016/j.marpol.2021.104532.
O'Donnell, T., T. F. Smith and S. Connor, 2019: Research Handbook on Climate Change Adaptation Policy. In: Property rights and land use planning on the Australian coast. Edward Elgar Publishing.
Oanh, P. T., M. Tamura, N. Kumano and Q. V. Nguyen, 2020: Cost-Benefit Analysis of Mixing Gray and Green Infrastructures to Adapt to Sea Level Rise in the Vietnamese Mekong River Delta. *Sustainability*, **12** (24), 10356.
OECD, 2018: Income inequality and poverty in cities. In: OECD Regions and Cities at a Glance 2018. OECD Publishing, Paris.
OECD, 2020: *OECD Regions and Cities at a Glance 2020*.
Olazabal, M. and M. Ruiz De Gopegui, 2021: Adaptation planning in large cities is unlikely to be effective. *Landscape and Urban Planning*, **206**, 103974, doi:https://doi.org/10.1016/j.landurbplan.2020.103974.
Olazabal, M. et al., 2019: A cross-scale worldwide analysis of coastal adaptation planning. *Environmental Research Letters*, **14** (12), 124056, doi:10.1088/1748-9326/ab5532.
Olthuis, K., P.-B. Tartas and C. Zevenbergen, 2020: Design Guidelines for Upgrading Living Conditions in Wetslums. Singapore, Springer Singapore, 1-18.
Ondiviela, B. et al., 2014: The role of seagrasses in coastal protection in a changing climate. *Coastal Engineering*, **87**, 158-168, doi:https://doi.org/10.1016/j.coastaleng.2013.11.005.
Ong, J. M. et al., 2016: Challenges in Build-Back-Better Housing Reconstruction Programs for Coastal Disaster Management: Case of Tacloban City, Philippines. *Coastal Engineering Journal*, **58** (01), 1640010, doi:10.1142/S0578563416400106.
Oppenheimer, M. et al., 2019: Chapter 4: Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)]. In press.
Parkinson, R. W. and D. E. Ogurcak, 2018: Beach nourishment is not a sustainable strategy to mitigate climate change. *Estuarine, Coastal and Shelf Science*, **212**, 203-209.
Pasquini, L., 2020: The urban governance of climate change adaptation in least-developed African countries and in small cities: the engagement of local decision-makers in Dar es Salaam, Tanzania, and Karonga, Malawi. *Climate and Development*, **12** (5), 408-419, doi:10.1080/17565529.2019.1632166.
Peel, J. and H. M. Osofsky, 2018: A Rights Turn in Climate Change Litigation? *Transnational Environmental Law*, **7** (1), 37-67, doi:10.1017/S2047102517000292.
Penning-Rowsell, E., 2020: Floating architecture in the landscape: climate change adaptation ideas, opportunities and challenges. *Landscape Research*, **45** (4), 395-411, doi:10.1080/01426397.2019.1694881.
Perkins, M. J. et al., 2015: Conserving intertidal habitats: What is the potential of ecological engineering to mitigate impacts of coastal structures? *Estuarine, Coastal and Shelf Science*, **167**, 504-515, doi:https://doi.org/10.1016/j.ecss.2015.10.033.
Pontee, N., S. Narayan, M. W. Beck and A. H. Hosking, 2016: Nature-based solutions: lessons from around the world. *Proceedings of the Institution of Civil Engineers - Maritime Engineering*, **169** (1), 29-36, doi:10.1680/jmaen.15.00027.
Pueyo-Ros, J., X. Garcia, A. Ribas and R. M. Fraguell, 2018: Ecological Restoration of a Coastal Wetland at a Mass Tourism Destination. Will the Recreational Value Increase or Decrease? *Ecological Economics*, **148**, 1-14, doi:https://doi.org/10.1016/j.ecolecon.2018.02.002.

Pugatch, T., 2019: Tropical storms and mortality under climate change. *World Development*, **117**, 172-182, doi:https://doi.org/10.1016/j.worlddev.2019.01.009.

Ramm, T. D., C. S. Watson and C. J. White, 2018: Strategic adaptation pathway planning to manage sea-level rise and changing coastal flood risk. *Environmental Science & Policy*, **87**, 92-101, doi:https://doi.org/10.1016/j.envsci.2018.06.001.

Ranganathan, M. and E. Bratman, 2019: From Urban Resilience to Abolitionist Climate Justice in Washington, DC. *Antipode*, doi:10.1111/anti.12555.

Reguero, B. G. et al., 2018: Comparing the cost effectiveness of nature-based and coastal adaptation: A case study from the Gulf Coast of the United States. *PLoS One*, **13** (4), e0192132, doi:10.1371/journal.pone.0192132.

Reguero, B. G. et al., 2020: Financing coastal resilience by combining nature-based risk reduction with insurance. *Ecological Economics*, **169**, 106487, doi:https://doi.org/10.1016/j.ecolecon.2019.106487.

Reiblich, J. et al., 2019: Bridging climate science, law, and policy to advance coastal adaptation planning. *Marine Policy*, **104**, 125-134, doi:https://doi.org/10.1016/j.marpol.2019.02.028.

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.

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** (7), 215, doi:https://doi.org/10.3390/jmse7070215.

Ribeiro, A. S. et al., 2021: Flooding Conditions at Aveiro Port (Portugal) within the Framework of Projected Climate Change. *Journal of Marine Science and Engineering*, **9** (6), 595.

Richards, D. R. and D. A. Friess, 2016: Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. *Proceedings of the National Academy of Sciences*, **113** (2), 344-349, doi:10.1073/pnas.1510272113.

Ristroph, E. B., 2017: When Climate Takes a Village: Legal Pathways toward the Relocation of Alaska Native Villages. *Climate Law*, **7** (4), 259-289, doi:https://doi.org/10.1163/18786561-00704003.

Ristroph, E. B., 2019: Improving Justice and Avoiding Colonization in Managing Climate Change Related Disasters: A Case Study of Alaska Native Villages. *American Indian Law Journal*, **7** (2), 5.

Rocle, N. et al., 2020: Paving the way to coastal adaptation pathways: An interdisciplinary approach based on territorial archetypes. *Environmental Science & Policy*, **110**, 34-45, doi:https://doi.org/10.1016/j.envsci.2020.05.003.

Rocle, N. and D. Salles, 2018: "Pioneers but not guinea pigs": experimenting with climate change adaptation in French coastal areas. *Policy Sciences*, **51** (2), 231-247, doi:10.1007/s11077-017-9279-z.

Roder, G., P. Hudson and P. Tarolli, 2019: Flood risk perceptions and the willingness to pay for flood insurance in the Veneto region of Italy. *International Journal of Disaster Risk Reduction*, **37**, 101172, doi:https://doi.org/10.1016/j.ijdrr.2019.101172.

Romero Manrique, D., S. Corral and Â. Guimarães Pereira, 2018: Climate-related displacements of coastal communities in the Arctic: Engaging traditional knowledge in adaptation strategies and policies. *Environmental Science & Policy*, **85**, 90-100, doi:https://doi.org/10.1016/j.envsci.2018.04.007.

Rosendo, S., L. Celliers and M. Mechisso, 2018: Doing more with the same: A reality-check on the ability of local government to implement Integrated Coastal Management for climate change adaptation. *Marine Policy*, **87**, 29-39, doi:https://doi.org/10.1016/j.marpol.2017.10.001.

Rovai, A. S. et al., 2018: Global controls on carbon storage in mangrove soils. *Nature Climate Change*, **8** (6), 534-538, doi:10.1038/s41558-018-0162-5.

Roy, M., S. Cawood, M. Hordijk and D. Hulme, 2016: *Urban Poverty and Climate Change*. Routledge advances in climate change research, Routledge.

Salas, R. N., J. M. Shultz and C. G. Solomon, 2020: The Climate Crisis and Covid-19 — A Major Threat to the Pandemic Response. *New England Journal of Medicine*, **383** (11), e70, doi:10.1056/NEJMp2022011.

Saleh, F. and M. P. Weinstein, 2016: The role of nature-based infrastructure (NBI) in coastal resiliency planning: A literature review. *Journal of Environmental Management*, **183**, 1088-1098, doi:https://doi.org/10.1016/j.jenvman.2016.09.077.

Salik, K. M., S. Jahangir, W. u. Z. Zahdi and S. u. Hasson, 2015: Climate change vulnerability and adaptation options for the coastal communities of Pakistan. *Ocean & Coastal Management*, **112**, 61-73, doi:https://doi.org/10.1016/j.ocecoaman.2015.05.006.

Sánchez-Arcilla, A. et al., 2016: Managing coastal environments under climate change: Pathways to adaptation. *Science of The Total Environment*, **572**, 1336-1352, doi:https://doi.org/10.1016/j.scitotenv.2016.01.124.

Sayers, P., C. Walsh and R. Dawson, 2015: Climate impacts on flood and coastal erosion infrastructure. *Infrastructure Asset Management*, **2** (2), 69-83, doi:10.1680/iasma.14.00040.

Schinko, T. et al., 2020: Economy-wide effects of coastal flooding due to sea level rise: a multi-model simultaneous treatment of mitigation, adaptation, and residual impacts. *Environmental Research Communications*, **2** (1), 015002, doi:10.1088/2515-7620/ab6368.

Schmutter, K., M. Nash and L. Dovey, 2017: Ocean acidification: assessing the vulnerability of socioeconomic systems in Small Island Developing States. *Regional Environmental Change*, **17** (4), 973-987, doi:doi:10.1007/s10113-016-0949-8.

Schneider, P. et al., 2020: A rising tide of adaptation action: Comparing two coastal regions of Aotearoa-New Zealand. *Climate Risk Management*, **30**, 100244, doi:https://doi.org/10.1016/j.crm.2020.100244.

Schoonees, T. et al., 2019: Hard Structures for Coastal Protection, Towards Greener Designs. *Estuaries and coasts*, **42** (7), 1709-1729, doi:10.1007/s12237-019-00551-z.

Schoutens, K. et al., 2019: How effective are tidal marshes as nature-based shoreline protection throughout seasons? *Limnology and Oceanography*, **64** (4), 1750-1762, doi:https://doi.org/10.1002/lno.11149.

Schuerch, M. et al., 2018: Future response of global coastal wetlands to sea-level rise. *Nature*, **561** (7722), 231-234, doi:10.1038/s41586-018-0476-5.

Scussolini, P. et al., 2017: Adaptation to Sea Level Rise: A Multidisciplinary Analysis for Ho Chi Minh City, Vietnam. *Water Resources Research*, **53** (12), 10841-10857, doi:10.1002/2017wr021344.

Seddon, N. et al., 2020: Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **375** (1794), 20190120, doi:doi:10.1098/rstb.2019.0120.

Seekamp, E., M. Jurjonas and K. Bitsura-Meszaros, 2019: Influences on coastal tourism demand and substitution behaviors from climate change impacts and hazard recovery responses. *Journal of Sustainable Tourism*, **27** (5), 629-648, doi:10.1080/09669582.2019.1599005.

Sengupta, D., R. Chen and M. E. Meadows, 2018: Building beyond land: An overview of coastal land reclamation in 16 global megacities. *Applied Geography*, **90**, 229-238, doi:https://doi.org/10.1016/j.apgeog.2017.12.015.

Sengupta, D., R. Chen, M. E. Meadows and A. Banerjee, 2020: Gaining or losing ground? Tracking Asia's hunger for 'new' coastal land in the era of sea level rise. *Science of The Total Environment*, **732**, 139290, doi:https://doi.org/10.1016/j.scitotenv.2020.139290.

Setiadi, R., J. Baumeister, P. Burton and J. Nalau, 2020: Extending Urban Development on Water: Jakarta Case Study. *Environment and Urbanization ASIA*, **11** (2), 247-265, doi:10.1177/0975425320938539.

Setzer, J. and L. C. Vanhala, 2019: Climate change litigation: A review of research on courts and litigants in climate governance. *WIREs Climate Change*, **10** (3), e580, doi:https://doi.org/10.1002/wcc.580.

Sharifi, A., 2020: Trade-offs and conflicts between urban climate change mitigation and adaptation measures: A literature review. *Journal of Cleaner Production*, **276**, 122813, doi:https://doi.org/10.1016/j.jclepro.2020.122813.

Shi, H. and A. Singh, 2003: Status and Interconnections of Selected Environmental Issues in the Global Coastal Zones. *AMBIO: A Journal of the Human Environment*, **32** (2), 145-152, 8.

Shultz, J. M., C. Fugate and S. Galea, 2020a: Cascading Risks of COVID-19 Resurgence During an Active 2020 Atlantic Hurricane Season. *JAMA*, **324** (10), 935-936, doi:10.1001/jama.2020.15398.

Shultz, J. M. et al., 2020b: Superimposed threats to population health from tropical cyclones in the prevaccine era of COVID-19. *The Lancet Planetary Health*, **4** (11), e506-e508, doi:10.1016/S2542-5196(20)30250-3.

Siders, A. R., 2019a: Managed Retreat in the United States. *One Earth*, **1** (2), 216-225, doi:https://doi.org/10.1016/j.oneear.2019.09.008.

Siders, A. R., 2019b: Social justice implications of US managed retreat buyout programs. *Climatic Change*, **152** (2), 239-257, doi:10.1007/s10584-018-2272-5.

Siders, A. R., M. Hino and K. J. Mach, 2019: The case for strategic and managed climate retreat. *Science*, **365** (6455), 761, doi:10.1126/science.aax8346.

Simpson, N. P. et al., 2021: A framework for complex climate change risk assessment. *One Earth*, **4** (4), 489-501, doi:https://doi.org/10.1016/j.oneear.2021.03.005.

So, S., B. Juarez, A. Valle-Levinson and M. E. Gillin, 2019: Storm surge from Hurricane Irma along the Florida Peninsula. *Estuarine, Coastal and Shelf Science*, **229**, 106402, doi:https://doi.org/10.1016/j.ecss.2019.106402.

Song, J. et al., 2018: Does planned retreat matter? Investigating land use change under the impacts of flooding induced by sea level rise. *Mitigation and adaptation strategies for global change*, **23** (5), 703-733, doi:10.1007/s11027-017-9756-x.

Sovacool, B. K., 2018: Bamboo Beating Bandits: Conflict, Inequality, and Vulnerability in the Political Ecology of Climate Change Adaptation in Bangladesh. *World Development*, **102**, 183-194, doi:https://doi.org/10.1016/j.worlddev.2017.10.014.

Spalding, M. D. et al., 2014: Coastal Ecosystems: A Critical Element of Risk Reduction. *Conservation Letters*, **7** (3), 293-301, doi:https://doi.org/10.1111/conl.12074.

Stark, J., T. Van Oyen, P. Meire and S. Temmerman, 2015: Observations of tidal and storm surge attenuation in a large tidal marsh. *Limnology and Oceanography*, **60** (4), 1371-1381, doi:10.1002/lno.10104.

Staudt, F. et al., 2021: The sustainability of beach nourishments: a review of nourishment and environmental monitoring practice. *Journal of Coastal Conservation*, **25** (2), 34, doi:10.1007/s11852-021-00801-y.

Sterzel, T. et al., 2020: Typology of coastal urban vulnerability under rapid urbanization. *PLoS One*, **15** (1), e0220936, doi:10.1371/journal.pone.0220936.

Stive, M. J. F. et al., 2013: A New Alternative to Saving Our Beaches from Sea-Level Rise: The Sand Engine. *Journal of Coastal Research*, 1001-1008, doi:10.2112/JCOASTRES-D-13-00070.1.

Storbjörk, S. and M. Hjerpe, 2021: Climate-proofing coastal cities: What is needed to go from envisioning to enacting multifunctional solutions for waterfront climate adaptation? *Ocean & Coastal Management*, **210**, 105732, doi:https://doi.org/10.1016/j.ocecoaman.2021.105732.

Strauss, B. H. et al., 2021: Economic damages from Hurricane Sandy attributable to sea level rise caused by anthropogenic climate change. *Nature Communications*, **12** (1), 2720, doi:10.1038/s41467-021-22838-1.

Sudmeier-Rieux, K. et al., 2021: Scientific evidence for ecosystem-based disaster risk reduction. *Nature Sustainability*, doi:10.1038/s41893-021-00732-4.
Sutton-Grier, A. E., K. Wowk and H. Bamford, 2015: Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. *Environmental Science & Policy*, **51**, 137-148.
Takagi, H., M. Esteban, T. Mikami and D. Fujii, 2016: Projection of coastal floods in 2050 Jakarta. *Urban Climate*, **17**, 135-145, doi:https://doi.org/10.1016/j.uclim.2016.05.003.
Tamura, M., N. Kumano, M. Yotsukuri and H. Yokoki, 2019: Global assessment of the effectiveness of adaptation in coastal areas based on RCP/SSP scenarios. *Climatic Change*, **152** (3), 363-377, doi:10.1007/s10584-018-2356-2.
Temmerman, S. and M. L. Kirwan, 2015: Building land with a rising sea. *Science*, **349** (6248), 588-589.
Tessler, Z. D. et al., 2015: Profiling risk and sustainability in coastal deltas of the world. *Science*, **349** (6248), 638, doi:10.1126/science.aab3574.
Thomas, A. et al., 2020: Climate Change and Small Island Developing States. *Annual Review of Environment and Resources*, **45** (1), 1-27, doi:10.1146/annurev-environ-012320-083355.
Thomas, A. and L. Benjamin, 2020: Non-economic loss and damage: lessons from displacement in the Caribbean. *Climate Policy*, **20** (6), 715-728, doi:10.1080/14693062.2019.1640105.
Thomas, K. et al., 2019: Explaining differential vulnerability to climate change: A social science review. *WIREs Climate Change*, **10** (2), e565, doi:https://doi.org/10.1002/wcc.565.
Thrush, S. F. et al., 2021: Cumulative stressors reduce the self-regulating capacity of coastal ecosystems. *Ecological Applications*, **31** (1), e02223, doi:https://doi.org/10.1002/eap.2223.
Tian, B., W. Wu, Z. Yang and Y. Zhou, 2016: Drivers, trends, and potential impacts of long-term coastal reclamation in China from 1985 to 2010. *Estuarine, Coastal and Shelf Science*, **170**, 83-90, doi:https://doi.org/10.1016/j.ecss.2016.01.006.
Tiggeloven, T. et al., 2020: Global-scale benefit–cost analysis of coastal flood adaptation to different flood risk drivers using structural measures. *Nat. Hazards Earth Syst. Sci.*, **20** (4), 1025-1044, doi:10.5194/nhess-20-1025-2020.
Toimil, A. et al., 2020: Climate change-driven coastal erosion modelling in temperate sandy beaches: Methods and uncertainty treatment. *Earth-Science Reviews*, **202**, 103110, doi:https://doi.org/10.1016/j.earscirev.2020.103110.
Torres, A., J. Brandt, K. Lear and J. Liu, 2017: A looming tragedy of the sand commons. *Science*, **357** (6355), 970, doi:10.1126/science.aao0503.
Triyanti, A., M. Bavinck, J. Gupta and M. A. Marfai, 2017: Social capital, interactive governance and coastal protection: The effectiveness of mangrove ecosystem-based strategies in promoting inclusive development in Demak, Indonesia. *Ocean & Coastal Management*, **150**, 3-11, doi:https://doi.org/10.1016/j.ocecoaman.2017.10.017.
Ung, M., I. Luginaah, R. Chuenpagdee and G. Campbell, 2016: Perceived self-efficacy and adaptation to climate change in coastal Cambodia. *Climate*, **4** (1), 1, doi:https://doi.org/10.3390/cli4010001.
Ürge-Vorsatz, D. et al., 2018: Locking in positive climate responses in cities. *Nature Climate Change*, **8** (3), 174-177, doi:10.1038/s41558-018-0100-6.
Valdivieso, P. and K. P. Andersson, 2018: What motivates local governments to invest in critical infrastructure? Lessons from Chile. *Sustainability*, **10** (10), 3808, doi:https://doi.org/10.3390/su10103808.
Van Assche, K., A.-K. Hornidge, A. Schlüter and N. Vaidianu, 2020: Governance and the coastal condition: Towards new modes of observation, adaptation and integration. *Marine Policy*, **112**, 103413, doi:https://doi.org/10.1016/j.marpol.2019.01.002.
Van Coppenolle, R. and S. Temmerman, 2020: Identifying Ecosystem Surface Areas Available for Nature-Based Flood Risk Mitigation in Coastal Cities Around the World. *Estuaries and coasts*, **43** (6), 1335-1344, doi:10.1007/s12237-020-00718-z.
van Valkengoed, A. M. and L. Steg, 2019: Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change*, **9** (2), 158-163, doi:10.1038/s41558-018-0371-y.
Villamizar, A. et al., 2017: Climate adaptation in South America with emphasis in coastal areas: the state-of-the-art and case studies from Venezuela and Uruguay. *Climate and Development*, **9** (4), 364-382, doi:10.1080/17565529.2016.1146120.
Vousdoukas, M. I. et al., 2020a: Economic motivation for raising coastal flood defenses in Europe. *Nature Communications*, **11** (1), 2119, doi:10.1038/s41467-020-15665-3.
Vousdoukas, M. I. et al., 2020b: Sandy coastlines under threat of erosion. *Nature Climate Change*, **10** (3), 260-263, doi:10.1038/s41558-020-0697-0.
Vuik, V., B. W. Borsje, P. W. J. M. Willemsen and S. N. Jonkman, 2019: Salt marshes for flood risk reduction: Quantifying long-term effectiveness and life-cycle costs. *Ocean & Coastal Management*, **171**, 96-110, doi:https://doi.org/10.1016/j.ocecoaman.2019.01.010.
Vuik, V., S. N. Jonkman, B. W. Borsje and T. Suzuki, 2016: Nature-based flood protection: The efficiency of vegetated foreshores for reducing wave loads on coastal dikes. *Coastal Engineering*, **116**, 42-56, doi:https://doi.org/10.1016/j.coastaleng.2016.06.001.
Vuik, V. et al., 2018: Assessing safety of nature-based flood defenses: Dealing with extremes and uncertainties. *Coastal Engineering*, **139**, 47-64, doi:https://doi.org/10.1016/j.coastaleng.2018.05.002.

Wahl, T. et al., 2015: Increasing risk of compound flooding from storm surge and rainfall for major US cities. *Nature Climate Change*, **5** (12), 1093-1097, doi:10.1038/nclimate2736.
Walker, W. E., M. Haasnoot and J. H. Kwakkel, 2013: Adapt or perish: a review of planning approaches for adaptation under deep uncertainty. *Sustainability*, **5** (3), 955-979.
Wallace, B., 2017: A framework for adapting to climate change risk in coastal cities. *Environmental Hazards*, **16** (2), 149-164, doi:10.1080/17477891.2017.1298511.
Walsh, C. et al., 2019: Trade and trade-offs: Shipping in changing climates. *Marine Policy*, **106**, 103537, doi:https://doi.org/10.1016/j.marpol.2019.103537.
Wang, C. M. and B. T. Wang, 2020: Floating Solutions for Challenges Facing Humanity. Singapore, Springer Singapore, 3-29, doi:10.1007/978-981-15-5144-4_1.
Wang, G., Y. Goldfeld and N. Drimer, 2019: Expanding coastal cities – Proof of feasibility for modular floating structures (MFS). *Journal of Cleaner Production*, **222**, 520-538, doi:https://doi.org/10.1016/j.jclepro.2019.03.007.
Wang, W., H. Liu, Y. Li and J. Su, 2014: Development and management of land reclamation in China. *Ocean & Coastal Management*, **102**, 415-425, doi:https://doi.org/10.1016/j.ocecoaman.2014.03.009.
Ward, R. D., 2020: Carbon sequestration and storage in Norwegian Arctic coastal wetlands: Impacts of climate change. *Science of The Total Environment*, **748**, 141343, doi:https://doi.org/10.1016/j.scitotenv.2020.141343.
Ware, D. and Z. Banhalmi-Zakar, 2020: Strategies for governments to help close the coastal adaptation funding gap. *Ocean & Coastal Management*, **198**, 105223, doi:https://doi.org/10.1016/j.ocecoaman.2020.105223.
Waryszak, P. et al., 2021: Combining gray and green infrastructure to improve coastal resilience: lessons learnt from hybrid flood defenses. *Coastal Engineering Journal*, 1-16, doi:10.1080/21664250.2021.1920278.
Weber, E., P. Kissoon and C. Koto, 2019: Moving to dangerous places. In: Dealing with climate change on small islands: Towards effective and sustainable adaptation [Klöck, C. and M. Fink (eds.)]. Universitätsverlag Göttingen, Göttingen.
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:https://doi.org/10.1016/j.worlddev.2017.11.001.
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.
Welch, A. C., R. J. Nicholls and A. N. Lázár, 2017: Evolving deltas: Coevolution with engineered interventions. *Elementa: Science of the Anthropocene*, **5**, doi:10.1525/elementa.128.
Wewerinke-Singh, M. and D. H. Salili, 2020: Between negotiations and litigation: Vanuatu's perspective on loss and damage from climate change. *Climate Policy*, **20** (6), 681-692, doi:10.1080/14693062.2019.1623166.
Wijaya, N., V. Nitivattananon, R. P. Shrestha and S. M. Kim, 2020: Drivers and Benefits of Integrating Climate Adaptation Measures into Urban Development: Experience from Coastal Cities of Indonesia. *Sustainability*, **12** (2), 750, doi:https://doi.org/10.3390/su12020750.
Williams, D. S., 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, B. J. et al., 2018: Declines in Plant Productivity Drive Carbon Loss from Brackish Coastal Wetland Mesocosms Exposed to Saltwater Intrusion. *Estuaries and coasts*, **41** (8), 2147-2158, doi:10.1007/s12237-018-0438-z.
Wong, P. P. et al., 2014: Coastal systems and low-lying areas. 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, P. R. Mastrandrea and L.L.White (eds.)]. Cambridge Univeristy Press, Cambridge, United Kingdom
New York, NY, USA, 361-409.
Woodruff, S. C., M. Mullin and M. Roy, 2020: Is coastal adaptation a public good? The financing implications of good characteristics in coastal adaptation. *Journal of Environmental Planning and Management*, **63** (12), 2082-2101, doi:10.1080/09640568.2019.1703656.
Xu, H., K. Xu, J. Lian and C. Ma, 2019: Compound effects of rainfall and storm tides on coastal flooding risk. *Stochastic Environmental Research and Risk Assessment*, **33** (7), 1249-1261, doi:10.1007/s00477-019-01695-x.
Yang, Y.-C. and Y.-E. Ge, 2020: Adaptation strategies for port infrastructure and facilities under climate change at the Kaohsiung port. *Transport Policy*, **97**, 232-244, doi:https://doi.org/10.1016/j.tranpol.2020.06.019.
Yesudian, A. N. and R. J. Dawson, 2021: Global analysis of sea level rise risk to airports. *Climate Risk Management*, **31**, 100266, doi:https://doi.org/10.1016/j.crm.2020.100266.
Yin, J. et al., 2020: Flood Risks in Sinking Delta Cities: Time for a Reevaluation? *Earth's Future*, **8** (8), e2020EF001614, doi:https://doi.org/10.1029/2020EF001614.
Yumagulova, L., 2020: Disrupting the riskscapes of inequities: a case study of planning for resilience in Canada's Metro Vancouver region. *Cambridge Journal of Regions, Economy and Society*, **13** (2), 293-318, doi:10.1093/cjres/rsaa029.
Zhang, J., F. Su and Z. Ding, 2017: Sea Reclamation Status of Countries around the South China Sea from 1975 to 2010. *Sustainability*, **9** (6), 878.

Zhao, Q. et al., 2018: Effects of water and salinity regulation measures on soil carbon sequestration in coastal wetlands of the Yellow River Delta. *Geoderma*, **319**, 219-229, doi:https://doi.org/10.1016/j.geoderma.2017.10.058.
Zhu, L. et al., 2020a: Aquaculture farms as nature-based coastal protection: Random wave attenuation by suspended and submerged canopies. *Coastal Engineering*, **160**, 103737, doi:https://doi.org/10.1016/j.coastaleng.2020.103737.
Zhu, Z. et al., 2020b: Historic storms and the hidden value of coastal wetlands for nature-based flood defence. *Nature Sustainability*, **3** (10), 853-862, doi:10.1038/s41893-020-0556-z.
Ziervogel, G., A. Cowen and J. Ziniades, 2016: Moving from adaptive to transformative capacity: Building foundations for inclusive, thriving, and regenerative urban settlements. *Sustainability*, **8** (9), 955, doi:https://doi.org/10.3390/su8090955.
Ziervogel, G. and S. Parnell, 2014: Tackling barriers to climate change adaptation in South African coastal cities. In: Adapting to climate change. Springer, 57-73.