V

Vulnerable Communities: The Need for Local-Scale Climate Change Adaptation Planning

Nicole Bonnett and S. Jeff Birchall
School of Urban and Regional Planning,
Department of Earth and Atmospheric Sciences,
University of Alberta, Edmonton, AB, Canada

Synonyms

Adjusting; Building resilience and preparedness for climate impacts; Coping; Managing; Regulating; Responding to

Definitions

Climate Change

The agreed upon definition of climate change, as established in the Intergovernmental Panel on Climate Change (IPCC) fifth synthesis report, "refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer" (IPCC 2014, p.120). Climate change, then, does not account for short-term variability and changes in weather but rather refers to long-term shifts in the observed average weather.

The term "climate change" is frequently expanded to "anthropogenic climate change" which accounts for the significant influence of humans on climate through persistent changes in the composition of the atmosphere (IPCC 2014). Natural processes, such as solar cycles and volcanic eruptions, also play a role in climate change (IPCC 2014).

Observed changes in the climate system broadly involve ocean and atmospheric warming, reduced snow and ice cover, and rising sea levels (IPCC 2014). From 1880 to 2012, the globally averaged land and ocean temperature has warmed by 0.85 degrees Celsius, the global mean sea level has rose by 0.19 meters over the period 1901–2010, and ice sheets, glaciers, and snow cover have been significantly reduced (IPCC 2014).

Adaptation

In the context of climate change, broadly defined adaptation refers to "the process of adjustment to actual or expected climate and its effects" (IPCC 2014, p.118). In human systems, the process of adaptation is employed to moderate or avoid harm associated with climate impacts and threats (IPCC 2014). In analyzing the costs and benefits of adaptation, Agrawala et al. (2011) describe adaptation as a complementary strategy used in combination with mitigation, to reduce the negative impacts of climate change. Climate change adaptation can then be viewed as a damage-reducing strategy.

W. Leal Filho et al. (eds.), *Climate Action*,
https://doi.org/10.1007/978-3-319-71063-1_87-1

Adaptation is often described alongside the concept of **proactivity**, which speaks to the anticipatory nature of climate change adaptation. While moderating harm arising in association with current climate impacts, adaptation can also be employed to prepare for future climate change.

Adaptation in human systems is highly variable and context specific. Adaptation efforts differ across the globe and between communities, in response to variable climate impacts and differing economic and social factors. Moreover, adaptation types are diverse and constantly evolving as new, innovative methods are developed and contemporary adaptations are examined.

Vulnerable Community

In its fifth assessment report, the IPCC differentiates exposure and vulnerability by highlighting that exposure refers to humans and assets that are at risk, while vulnerability speaks to the susceptibility of human and natural systems to harm (IPCC 2014). Vulnerability can then be characterized as the tendency or likelihood of human and natural systems to be adversely affected by climate impacts and threats. Building off this definition, Adger et al. (2003) identify factors that contribute to the vulnerability of a system to climate change. These factors include the exposure, physical setting and sensitivity, and capacity of a system to adapt. In addition to these influencing variables, the vulnerability of a community may also depend on the impact of climate change on key resources, social and economic aspects, and the geographical location of communities (Adger et al. 2003; IPCC 2014).

According to this understanding of vulnerability and exposure, a community that is situated in a low-lying coastal area displays a high sensitivity to climate threats. This sensitivity stems from the proximity to the coast and subsequent susceptibility to flooding and extreme weather, reliance on marine resources that are inherently impacted by climate change, and exposure of assets and infrastructure to climate variability.

Vulnerability is not spatially consistent given that climate impacts are not evenly distributed and the elements that make up a vulnerable community are variable. The distribution of wealth, demographics, adaptive capacity, and governance structures influences a society's susceptibility to climate impacts (IPCC 2014). For example, poor societies in developing nations are highly vulnerable to a changing climate.

Examples

Examples of climate change adaptation can be observed in cases around the world:

- The construction of seawalls in regions which are highly vulnerable to storm surge and flooding, such as the Gilbert Islands (Duvat 2013)
- The managed relocation of residents and assets in response to threats associated with sea-level rise and increasing storm activity, as seen in the case of Grantham, Australia (Sipe and Vella 2014)
- The establishment of setbacks across communities in North America to provide a buffer between hazardous coastal areas and development (Harman et al. 2015.
- The undertaking of ecosystem-based efforts, such as mangrove planting and restoration, to respond to sea-level rise and storm surges (Cheong et al. 2013.

Introduction

Global Climate Change

Global climate change is broadly recognized as one of the most significant challenges facing society today (Birchall and Bonnett 2018). In its most recent assessment report, the IPCC highlighted the influence of anthropogenic activities and declared that many of the observed climate impacts are unprecedented over decades to millennia (IPCC 2014).

Increasing concentrations of atmospheric greenhouse gas emission, largely associated with activities such as fossil fuel combustion, deforestation, and agriculture, are leading to higher global temperatures. The rise in global temperature has spurred multiple climate impacts around the world, posing direct challenges for both coastal and inland communities.

Warming of the climate system is unequivocal, sea levels are rising at an increasingly rapid rate, glaciers and ice sheets have diminished drastically, and precipitation and weather events have become highly variable (IPCC 2014). Many coastal communities have been confounded by sea-level rise (SLR) and intense storm surges, wildfires have ravaged vast areas of human settlement, and extreme weather events frequently overwhelm cities across the globe. Human systems are at the forefront of climate risks (e.g., Birchall et al. 2017) and highly vulnerable to contemporary climate variability, as evidenced by the devastating effect of heat waves, droughts, floods, hurricanes, and wildfires (IPCC 2014).

Vulnerability of Coastal Communities

Given their geographic location, population density, dependence on marine resources, and exposure to various climate threats, coastal communities exhibit a markedly high vulnerability to climate change. Moreover, many coastal locations are challenged by the need to respond to immediate threats which consume resources needed to prepare for future climate impacts, thus hindering anticipatory action. From a geographic perspective, the proximity of coastal communities to the sea translates into greater climate risks associated with rising sea levels and sea surface temperatures, ocean acidification, storm surges, and extreme weather. SLR is one of the most visible impacts of climate change and is characterized as a slow-onset challenge given its delayed rate of impact. While SLR will translate into a persistent problem in the future, preparing for its effect must not be overlooked. Without anticipatory action, coastal locations will face mass SLR-induced displacement. Estimates of human displacement as a result of SLR vary substantially, with predictions ranging from 67 million to 187 million people at risk with a one-meter rise in sea level (Geisler and Currens 2017). In addition to rising sea levels, ocean warming contributes to coastal vulnerability. Rising sea surface temperatures create a dangerous scenario that increases the formation and duration of extreme weather events such as hurricanes. Because these weather systems originate over the sea, they disproportionately threaten coastal areas. Alongside their exposure to rising sea levels and intense weather events, coastal areas are densely populated, thus representing a concentration of infrastructure and population inherently vulnerable to climate threats (Nicholls et al. 2008). Further population growth, urbanization, and economic development will accentuate coastal vulnerability and exposure (IPCC 2014). This raises concerns associated with the susceptibility of human and natural systems to harm and highlights the need for intervention.

Global Policy Approach

Action on climate change can occur through a number of efforts and strategies. Scholars have identified two major components necessary for a robust response: mitigation and adaptation. Mitigation is a "human intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC 2014, p.125). Adaptation, on the other hand, seeks to minimize or avoid harm by adjusting human and natural systems to cope with climate impacts (IPCC 2014).

The current global policy approach to addressing climate change is dominated by a focus on mitigation (e.g., Birchall 2014; Birchall et al. 2015, 2017), while adaptation receives significantly less attention. Adaptation has only recently emerged in policy discourse as a critical component required to address global climate impacts. This is because some degree of climate change is inevitable even with aggressive mitigation. Adapting to climate change is thus imperative if human systems are to reduce costs, remain resilient, and protect residents and assets (Noble et al. 2014). Because of their legal authority, technical capacity, and resources to mandate adaptation across sectors, governments play a key role in developing and implementing adaptation policy (Henstra 2016). However, adaptation alone does not constitute the best response to climate variability. Indeed, adaptation and mitigation are complementary strategies and must be employed together if climate policy is to be effective (Bosello et al. 2010). While understanding of the need to adapt is gaining global interest, implementation of adaptive strategies remains limited and largely incremental (Wise et al. 2014). With that said, the 2015 Paris Agreement calls for efforts to adapt to the effects of climate change (UNFCC 2015). This transition toward a greater inclusion of adaptation efforts within global climate change policy exemplifies the evolving realization of the need to adapt.

Urgency of Adaptation

A reliance on mitigative strategies to reduce GHG emissions alone is not sufficient knowing that even with ambitious emissions reduction efforts, continued climate change is unavoidable (Klein et al. 2005; IPCC 2014). Adaptation is thus a necessity. This is evident in Kiribati, for example, where its 32 low-lying atolls are experiencing extensive inundation, forcing hundreds of residents from their homes (Donner and Webber 2014). Lacking sufficient adaptive capacity, residents of vulnerable Kiribati islands are facing relocation to other countries as the sea level continues to rise (Donner and Webber 2014). Without anticipatory adaptation, the threat of climate change becomes immense.

Several climate change experts have projected the extent of human displacement and land inundation under future SLR. In the United States alone, Hauer et al. (2016) have projected that if the sea level were to rise 0.9 meters by the year 2100, it would cause massive coastal flooding, putting 4.2 million individuals at risk. Thus, for coastal regions threatened by SLR, anticipatory adaptation has been encouraged as a cost-effective and damage-reducing strategy. However, as a result of the influence of policy measures, the implementation of adaptive efforts has been sparse (Diaz 2016). Even though the full effects of climate change are not currently evident, action must be taken now to prevent a crisis.

Adaptation Types

A number of adaptation initiatives have been pursued to improve the well-being of populations, the security of assets, and the health of natural ecosystems now and in the future (Marolla and Sommer 2016). Adaptation actions are commonly divided into structural-, nonstructural-, and ecosystem-based approaches (Wenger 2015). Structural adaptations tend to be preferred in coastal regions and, as a result, represent a heavily relied upon traditional pathway. Nonstructural adaptation types, on the other hand, tend to be less common; however, there is a growing realization of their potential. As an innovative option, ecosystem-based approaches are rarely utilized in coastal adaptation planning, but present numerous opportunities for contributing to resilience. The following sections focus on the adaptation types most relevant in vulnerable coastal communities, in the context of SLR, coastal erosion, and violent weather.

Structural Approaches

Structural adaptations, or hard adaptations, are described as an infrastructural change or improvement, aimed at increasing a community's resilience to climate impacts. Structural approaches vary drastically according to the specific climate impact in question. For example, hard adaptations engineered to protect against flooding and to divert water flows include levees, seawalls, drainage channels, and dams (Wenger 2015). In vulnerable coastal communities, adaptation strategies tend to focus on shoreline armoring or hardening, including breakwaters, ripraps, and seawalls (Goff 2010). Shoreline armoring is intended to reduce coastal damage by absorbing the force of wave action and storm surges. Such adaptation efforts aim to utilize engineering and technological responses that physically protect residents and assets from climate threats.

Globally, structural responses tend to be favored because of the perceived security that comes with hard infrastructure and the extensive history of their use (Betzold and Mohamed 2016). One of the oldest dike systems, erected in Germany 1000 years ago to protect farmland from flooding, exemplifies the deep-rooted nature of these responses (Harman et al. 2015). Because structural responses have long served as a protective measure in vulnerable coastal regions, many countries are currently faced with maintaining and upgrading their hard adaptations in response to SLR-induced flooding (Harman et al. 2015). Moreover, global analysis of the effectiveness and efficiency of structural adaptations reveals associated challenges and indirect effects that are frequently overlooked. To address these challenges and build resilience, communities must sever their reliance on physical structures and incorporate nonstructural- and ecosystem-based approaches into their adaptation planning.

Nonstructural Approaches

By contrast, nonstructural approaches, a type of soft adaptation, reflect the concept of accommodation, focus on human behavior, and attempt to manage risks primarily by regulating land use and development. Harman et al. (2015) describe nonstructural adaptations as measures that aim to permit the continued use of vulnerable areas by reducing the sensitivity, exposure, or both to climate impacts. Such measures include planned relocation or retreat, altered land use and building controls, elevated floor and increased setback requirements, and enhanced awareness, emergency management, and insurance (Harman et al. 2015; Wenger 2015). These efforts aim to make development more resilient to climate impacts and manage risk through public education and awareness. Nonstructural adaptations are less common in adaptation planning; however, they represent a valid response to climate change. These approaches are relatively flexible and can be tailored to specific climate impacts. For example, to mitigate flood risks and threats associated with storm surges and violent weather, communities can alter their development regulations and building codes to protect residents and assets. This protection occurs by ensuring that development is located and designed in a resilient manner. For example, exaggerated setbacks, if implemented appropriately, can provide a buffer between hazardous areas and coastal development (Harman et al. 2015).

Planned retreat or relocation, on the other hand, is viewed to be a more extreme approach. Alexander et al. (2012) describe managed retreat as a process involving the relocation of homes and infrastructure under threat from climate impacts. The intent of relocation is to migrate residents and assets out of hazard-prone areas, which presents significant opportunities for risk reduction and climate change adaptation. While structural adaptations aimed at protecting residents and built assets can be expensive, relocation may provide a range of benefits now and in the future (IPCC 2014). Relocation is increasingly considered a valid coastal adaptation measure, as evidenced by the establishment of buy-out programs post Hurricane Sandy and relocation attempts in Alaska (Bukvic et al. 2015; Bronen and Chapin 2013). The legitimacy of relocation as an adaptation option, however, is frequently examined in the literature, which tends to focus on the array of challenges derived from this strategy (e.g., Binder et al. 2015).

In general, recent research on nonstructural adaptations find that this approach is inherently challenged by financial, social, and political constraints. In an attempt to overcome the many drawbacks of hard infrastructure and nonstructural adaptations, ecosystem-based approaches have been cited as flexible, cost-effective, and applicable alternatives for addressing the impacts of climate change (Jones et al. 2012).

Ecosystem-Based Approaches

Also referred to as soft defenses, ecosystem-based approaches are categorized as protective strategies that adapt to and supplement natural processes by leveraging the adaptive opportunities associated with ecosystem services (Harman et al. 2015). Jones et al. (2012) highlight that ecosystem-based approaches to adaptation act to buffer human systems against the impacts of climate change by capturing a range of ecosystem services provided. Climate and policy researchers are attracted to these strategies as they are flexible, low-regret, and low-cost and offer aesthetic and recreational opportunities (Harman et al. 2015; Jones et al. 2012).

Ecosystem-based approaches may involve large-scale projects such as beach nourishment and sand dune restoration (Harman et al. 2015). On a narrower scale, these approaches may also focus on specific species by capturing the adaptive opportunities offered by ecosystem engineering species such as mussel and oyster beds and vegetation (Borsje et al. 2011). Some researchers suggest that these species possess the ability to naturally moderate climate threats through a range of ecosystem services provided (Jones et al. 2012).

With extreme weather events increasing in severity and frequency, ecological systems become critical for increasing resilience and adaptive capacity in coastal areas. This concept is a form of insurance value where wetlands, naturalized shores, and marshes can reduce damage caused by flooding. This protection stems from the ability of these various species to trap and stabilize sediment, thus raising the soil elevation, which attenuates waves and shows potential to keep pace with SLR (Borsje et al. 2011). Ecosystem-based approaches may then be used in combination with structural approaches, as in the case of foreland vegetation restoration, to minimize the forces placed on seawalls and dams (Borsje et al. 2011). The contribution of ecosystem services to resilience is gaining global attention as a critical response to a changing climate; however, less is known about the ability of natural systems to contribute to resilience in monetary metrics (Gómez-Baggethun and Barton 2013). This limitation highlights a key challenge with ecosystem-based approaches as the process of ecosystem preservation and restoration lacks a valid economic justification. Thus, it is critical that decision-makers and policy creators realize the value of ecosystem-based options as an approach to enhance resilience and quality of life in coastal cities (Gómez-Baggethun and Barton 2013). Despite this limitation, the challenges associated with hard adaptation types and soft, nonstructural adaptations far outweigh the challenges with ecosystem-based approaches.

Key Issues

Global climate change is a wicked problem posing distinct and long-term challenges. Climate change scholars and policy makers have highlighted that a robust response to a changing climate should involve components of both mitigation and adaptation. Although mitigation dominates climate interventions (Broto and Bulkeley 2013), the stipulation for adaptation is rapidly growing. The urgency of adaptation emanates from the fact that some degree of continued climate change is inevitable, even with the most aggressive emissions reduction strategies. Moreover, climate impacts have already had a widespread and marked effect on human and natural systems, warranting the need to adapt (IPCC 2014). These systems are inherently vulnerable to climate threats with vulnerabilities predicted to increase with further climate warming (IPCC 2014).

Coastal communities, in particular, show an enhanced vulnerability to climate change impacts as a result of their geographic location, population density, dependence on marine resources, and exposure to various climate threats. As a result of sea-level rise, coastal systems will be increasingly subject to submergence, flooding, and erosion throughout the twenty-first century (IPCC 2014). Additionally, this vulnerability will be accentuated due to population growth, urbanization, and economic development which contribute to an increased exposure of human populations and assets (IPCC 2014). To moderate or avoid harm and increase their resilience and reduce vulnerabilities, coastal communities can undertake several adaptation efforts which may fall into the categories of structural-, nonstructural-, and/or ecosystem-based approaches (Wenger 2015).

Current adaptation planning in coastal regions tends to rely on the use of hard adaptations as a result of its long-standing use over time, perceived security, and ease of implementation. For example, several small island developing states, the United States, and Australia exhibit a significant reliance on seawalls, which cover great expanses of the shoreline (Goff 2010; Duvat 2013). However, hard adaptations are rigid, capital intensive, and frequently trigger some extent of ecosystem degradation. In response, soft adaptations can be pursued in lieu of, or in combination with, hard approaches. Nonstructural adaptations and ecosystem-based approaches are associated with greater flexibility, are less capital intensive, and incorporate long-term outlooks which promote climate change preparedness. The following section will contrast, in more detail, the various adaptation types.

Hard Versus Soft Adaptations

Hard adaptation pathways include structural, physical, or technological efforts while soft adaptations involve the use of nonstructural- and ecosystem-based approaches. With climate change threats continuing to unfold in coastal areas across the globe, new pathways are needed to address the complex challenges which arise. Contemporary adaptation planning tends toward a reliance on hard structures to protect residents and assets from climate threats and to reduce community vulnerability. However, hard adaptations are accompanied by a number of unforeseen and well-studied negative impacts. For example, while seawalls offer protective measures in the short term, they impact coastal processes in such a way that vulnerability may be accentuated in the long term (Duvat 2013; Kittinger and Ayers 2010). This is a result of their contribution to coastal erosion and destabilization, which are processes often left out of adaptation decision-making. Moreover, hardening of the coastline through the construction of seawalls has been proven to reduce the ability of natural systems to withstand disturbances, thus resulting in shoreline loss through erosion (Kittinger and Ayers 2010). Similarly, the construction of dams and levees has the consequence of degrading riparian ecosystems by interfering with natural flow regimes and preventing the interaction of rivers with their floodplains (Wenger 2015).

While hard adaptations are a familiar response to climate variability, offer a sense of security, and are temporally efficient strategies, they are often criticized within the literature. Adaptation pathways dominated by hard adaptations frequently involve large-scale disturbances to natural ecosystems and to the communities who pursue such a pathway (Sovacool 2011). Ecosystem degradation has long been a side effect of human population growth and development; however, the healthy functioning of natural ecosystems is now gaining recognition as a critical contributor to a communities' ability to adapt.

Hard adaptations encompass a rigidity that may not comprise a suitable response to climate impacts given the uncertainty and complexity associated with climate change (Sovacool 2011). This rigidity works to challenge a community's ability to respond to immediate climate threats and sudden changes in climate projections and thus has the potential to increase, rather than decrease, its vulnerability (Sovacool 2011). Lastly, hard adaptations are criticized for their complexity and capital-intensive nature (Sovacool 2011). Highly vulnerable coastal communities are oftentimes located in developing nations lacking the capacity to undertake and implement effective structural adaptations. In contrast, soft adaptation pathways are cited to be a less capital-intensive option (Sovacool 2011) and, however, present a suite of distinct challenges as well.

Nonstructural adaptation types such as development regulations and risk awareness are characterized as being more flexible and cost-effective strategies that supersede short-term structural responses to climate change (Sovacool 2011). For example, the designation of flood-prone zones and subsequent prevention of development in vulnerable areas physically remove residents and assets from areas of potential threats. Thus, long-term impacts are accounted for rather than relying on protection from threats as they arise. As noted earlier, nonstructural adaptations are not without their challenges. For example, when examining the challenges associated with the use of setbacks and other development and building controls, it was revealed that over time, this strategy may be compromised resulting in a heightened vulnerability as SLR reduces the protective buffer (Harman et al. 2015). In response, local governments must frequently review and update the setback restrictions. Planned retreat and relocation efforts are also frequently reviewed in climate change literature with several experts noting the barriers and potential negative effects associated with this pathway.

Managed retreat strategies may increase market uncertainty, reduce land values, spur social inequity and compensation claims, and negatively affect the collective sense of place of residents of coastal communities (Alexander et al. 2012; Adams 2016). The process of relocation itself is also vulnerable to several constraints including issues with choosing a suitable resettlement site, financial challenges, the timing and length of time involved in the relocation, and the broad willingness of a community to relocate (Sipe and Vella 2014; Binder et al. 2015). Moreover, governance and institutional barriers exist and consist of a lack of authority to relocate community infrastructure, a deficiency of specific funding and guidelines, and development regulations that hinder quick relocation. Viewed as a last resort, relocation remains a possible response for vulnerable coastal communities with very few instances of its implementation. Similarly, ecosystem-based approaches are rare in practice and, however, offer several adaptation opportunities for coastal regions impacts by climate change threats.

Ecosystem engineering is gaining vigor among climate scientists and policy makers, as a strategy that promotes sustainability, is highly flexible and self-preserving, and generates synergistic effects (Cheong et al. 2013). Ecosystem-based adaptations such as the preservation and growth of oyster reefs, mangroves, and wetlands promote a greater level of preparedness for climate threats in a highly complex and dynamic coastal environment (Cheong et al. 2013). Integrating ecosystem engineering into contemporary coastal management projects can increase a communities' resilience by harnessing the stabilizing effect of natural ecosystems. Cheong et al. (2013) highlights that climate impacts are more easily absorbed and recovered from when ecosystem-based approaches are used in tandem with other adaptation efforts. Moreover, pursuing ecosystem-based strategies presents benefits that extend beyond coastal resilience to provide social opportunities as well. For example, the preservation of natural systems in proximity to structural adaptations can increase the cumulative protection of assets and residents while presenting recreational opportunities. Challenges with leveraging ecosystem-based approaches largely stem from the lack of methods available to evaluate and quantify these efforts (Cheong et al. 2013; Gómez-Baggethun and Barton 2013).

Given the range of climate change threats presented and differing economic and social factors contributing to a communities' vulnerability, there exists no single adaptation solution. While hard adaptations represent a familiar and historically utilized strategy that quickly responds to immediate climate threats, challenges related to rigidity, cost, and ecosystem degradation effects are frequently encountered. In contrast, soft adaptations are associated with greater flexibility, are less capital intensive, and incorporate long-term outlooks which promote climate change preparedness. For efficient adaptation planning to occur, decision-makers must be aware of the various adaptation pathways to pursue, including the opportunities and constraints associated with differing adaptation types. In general, to generate synergistic effects and to develop a robust response to climate impacts, a combination of adaptation efforts is frequently recommended.

Future Directions

Further research is needed to understand climate change and its effects. Prior to identifying options to advance the adaptation planning process at the local governmental level, it is important to note the needed changes at senior levels of government. Ultimately, a transition in the global climate change policy approach is required from a mitigation focus to one that integrates critical components of adaptation. Such a transition which emphasizes the urgency of adaptation at senior levels of government will provide a robust framework to guide and influence the actions of impacted communities. Without such guidance, local efforts to ensure that climate change adaptation is a priority and to push adaptation through to implementation may not be realized, resulting in a fragmented approach that receives little attention in contrast to other local priorities (Krellenberg and Katrin 2014).

At the decision-making level, scholars have devised a number of recommendations to improve contemporary adaptation planning. In response to the host of criticisms associated with hard adaptations, updated adaptation pathways must be explored which may promote a combination of adaptation types, the replacement of hard adaptations with soft or a re-envisioning of hard adaptations. Combining adaptation types is gaining traction among climate scientists as a more robust adaptation pathway. Combining hard and soft adaptation efforts offers a greater flexibility and generates synergies and, simultaneously, acts to reduce the political, financial, and infrastructural constraints associated with planning and decision-making (Cheong et al. 2013).

A complete replacement of structural strategies with soft adaptations is less frequently encouraged among climate scholars and however responds to the ineffectiveness of hard strategies. A more suitable direction to pursue is the repurposing and envisioning of hard adaptation structures. This may involve the use of different materials to construct seawalls and dams which allow for the preservation and growth of biological species that assist in the reduction of coastal erosion (Goff 2010). Ultimately, vulnerable coastal communities must expand their knowledge on adaptation strategies through education and awareness programs, prioritize adaptation as a critical response to climate change, and make adjustments in their adaptation planning process to reduce vulnerabilities and increase their overall resilience.

Cross-References

- ▶ Adaptation
- ▶ Climate Change Adaptation (CCA)
- ▶ Climate Change and Human Migration as Adaptation ("Climate Refugees")
- ▶ Climate Change Effects Natural and Human Systems
- ▶ Climate Change Impacts and Resilience
- ▶ Climate Change Planning
- ▶ Climate Resilient Communities
- ▶ Community Planning Opportunities
- ▶ Immediate Climate Vulnerabilities
- ▶ Long-Term Climate Vulnerabilities
- ▶ Vulnerability

References

Adams H (2016) Why populations persist: mobility, place attachment and climate change. Popul Environ 37:429–448. https://doi.org/10.1007/s11111-015-0246-3

Adger WN, Huq S, Brown K et al (2003) Adaptation to climate change in the developing world. Prog Dev Stud 3:179–195. https://doi.org/10.1191/1464993403ps060oa

Agrawala S, Bosello F, Carraro C, De Cian E, Lanzi E (2011) Adapting to climate change: costs, benefits, and modelling approaches. Int Rev Environ Resour Econ 5:245–284. https://doi.org/10.1561/101.00000043

Alexander KS, Ryan A, Measham TG (2012) Managed retreat of coastal communities: understanding responses to projected sea level rise. J Environ Plan Manag 55:409–433. https://doi.org/10.1080/09640568.2011.604193

Betzold C, Mohamed I (2016) Seawalls as a response to coastal erosion and flooding: a case study from Grande Comore, Comoros (West Indian Ocean). Reg Environ Chang 17:1077–1087. https://doi.org/10.1007/s10113-016-1044-x

Binder SB, Baker CK, Barile JP (2015) Rebuild or relocate? Resilience and postdisaster decision-making after Hurricane Sandy. Am J Community Psychol 56:180–196. https://doi.org/10.1007/s10464-015-9727-x

Birchall J (2014) New Zealands abandonment of the carbon neutral public service programme. Clim Pol 14:525–535. https://doi.org/10.1080/14693062.2014.877224

Birchall SJ, Murphy M, Milne MJ (2015) Evolution of the New Zealand voluntary carbon market: an analysis of CarboNZero client disclosures. Soc Environ Account J 35:142–156. https://doi.org/10.1080/0969160x.2015.1061444

Birchall SJ, Murphy M, Milne M (2017) An investigation into the early stages of New Zealand's voluntary carbon market. Carbon Management 9:71–81. https://doi.org/10.1080/17583004.2017.1418596

Birchall SJ, Bonnett N (2018) Local-scale climate change stressors and policy response: The case of Homer, Alaska. Environmental Planning and Management. https://doi.org/10.1080/09640568.2018.1537975

Borsje BW, van Wesenbeeck BK, Dekker F, Paalvast P, Bouma TJ, van Katwijk MM, de Vries MB (2011) How ecological engineering can serve in coastal protection. Ecol Eng 37(2):113–122. https://doi.org/10.1016/j.ecoleng.2010.11.027

Bosello F, Carraro C, Cian ED (2010) Climate policy and the optimal balance between mitigation, adaptation and unavoided damage. SSRN Electron J. https://doi.org/10.2139/ssrn.1606222

Bronen R, Chapin FS (2013) Adaptive governance and institutional strategies for climate-induced community relocations in Alaska. Proc Natl Acad Sci 110:9320–9325. https://doi.org/10.1073/pnas.1210508110

Broto VC, Bulkeley H (2013) A survey of urban climate change experiments in 100 cities. Glob Environ Chang 23(1):92–102. https://doi.org/10.1016/j.gloenvcha.2012.07.005

Bukvic A, Smith A, Zhang A (2015) Evaluating drivers of coastal relocation in Hurricane Sandy affected communities. Int J Disaster Risk Reduct 13:215–228. https://doi.org/10.1016/j.ijdrr.2015.06.008

Bulkeley H, Tuts R (2013) Understanding urban vulnerability, adaptation and resilience in the context of climate change. Local Environ 18:646–662. https://doi.org/10.1080/13549839.2013.788479

Cheong S-M, Silliman B, Wong PP et al (2013) Coastal adaptation with ecological engineering. Nat Clim Chang 3:787–791. https://doi.org/10.1038/nclimate1854

Donner SD, Webber S (2014) Obstacles to climate change adaptation decisions: a case study of sea-level rise and coastal protection measures in Kiribati. Sustain Sci 9:331–345. https://doi.org/10.1007/s11625-014-0242-z

Duvat V (2013) Coastal protection structures in Tarawa Atoll, Republic of Kiribati. Sustain Sci 8:363–379. https://doi.org/10.1007/s11625-013-0205-9

Geisler C, Currens B (2017) Impediments to inland resettlement under conditions of accelerated sea level rise. Land Use Policy 66:322–330. https://doi.org/10.1016/j.landusepol.2017.03.029

Goff M (2010) Evaluating habitat enhancements of an urban intertidal seawall: ecological responses and management implications. Doctoral dissertation, University of Washington

Gómez-Baggethun E, Barton DN (2013) Classifying and valuing ecosystem services for urban planning. Ecol Econ 86:235–245. https://doi.org/10.1016/j.ecolecon.2012.08.019

Harman BP, Heyenga S, Taylor BM, Fletcher CS (2015) Global lessons for adapting coastal communities to protect against storm surge inundation. J Coast Res 314:790–801. https://doi.org/10.2112/jcoastres-d-13-00095.1

Hauer ME, Evans JM, Mishra DR (2016) Millions projected to be at risk from sea-level rise in the continental United States. Nat Clim Chang 6:691–695. https://doi.org/10.1038/nclimate2961

Henstra D (2016) The tools of climate adaptation policy: analysing instruments and instrument selection. Clim Pol 16(4):496–521. https://doi.org/10.1080/14693062.2015.1015946

IPCC (2014) Climate change 2014: synthesis report. contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change. In: Core Writing Team, Pachauri RK, Meyer LA (eds). IPCC, Geneva, 151pp

Jones HP, Hole DG, Zavaleta ES (2012) Harnessing nature to help people adapt to climate change. Nat Clim Chang 2:504–509. https://doi.org/10.1038/nclimate1463

Kittinger JN, Ayers AL (2010) Shoreline armoring, risk management, and coastal resilience under rising seas. Coast Manag 38:634–653. https://doi.org/10.1080/08920753.2010.529038

Klein RJ, Schipper ELF, Dessai S (2005) Integrating mitigation and adaptation into climate and development policy: three research questions. Environ Sci Pol 8:579–588. https://doi.org/10.1016/j.envsci.2005.06.010

Krellenberg K, Katrin B (2014) Inter- and transdisciplinary research for planning climate change adaptation responses: the example of Santiago de Chile. Interdiscip Sci Rev 39:360–375. https://doi.org/10.1179/0308018814z.00000000097

Marolla C, Sommer DA (2016) Climate health risks in megacities. CRC Press. https://doi.org/10.1201/9781315367323

Nicholls RJ, Wong PP, Burkett V, Woodroffe CD, Hay J (2008) Climate change and coastal vulnerability assessment: scenarios for integrated assessment. Sustain Sci 3(1):89–102. https://doi.org/10.1007/s11625-008-0050-4

Noble IR, Huq S, Anokhin YA, Carmin J, Goudou D, Lansigan FP, Osman-Elasha B, Villamizar A (2014) Adaptation needs and options. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR (eds) 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

Sovacool BK (2011) Hard and soft paths for climate change adaptation. Clim Pol 11:1177–1183. https://doi.org/10.1080/14693062.2011.579315

UNFCC (2015) Paris agreement to the United Nations framework convention on climate change adopted at COP3 in Paris, France, on 12 Dec 2015

Wenger C (2015) Better use and management of levees: reducing flood risk in a changing climate. Environ Rev 23:240–255. https://doi.org/10.1139/er-2014-0060

Wise R, Fazey I, Smith MS et al (2014) Reconceptualising adaptation to climate change as part of pathways of change and response. Glob Environ Chang 28:325–336. https://doi.org/10.1016/j.gloenvcha.2013.12.002