Where land meets sea: islands, erosion and the thing-power of hard coastal protection structures

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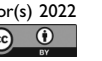

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Abstract

In the last few decades, hard coastal protection structures, such as seawalls and groynes, have become increasingly commonplace around the world. Conventionally, the effects of such structures have been considered within a modernist framework that evaluates the degree of human control over the land–sea interface. However, this dominant viewpoint overlooks the central role that sea defences play in the ongoing production of coastal communities, particularly in small island states. This paper responds to these issues by revealing how coastal protection structures, as contingently performed material configurations, are devised and come into being and the social relations that these structures create and influence. Drawing on empirical research undertaken on a small island in the Maldives over a period of 6 years, the paper demonstrates not only the challenges that coastal communities face in attempting to exert control over the unruly sea but also the thing-power of the protection measures themselves that are made and unmade as part of this process. These findings suggest the need for sensitivity towards the social roles and effects of hard coastal protection structures when devising approaches and policies that might see the decommissioning of such structures in favour of softer, 'nature-based' responses to the vitality of the non-human world. As structures with their own unique material complexities, hard defence measures are deeply involved in the production of multinatural island futures.

Keywords

Islands, beach erosion, coastal protection, new materialism, Maldives

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Introduction

In recent years, problems of erosion, flooding and sea level rise have intensified debates among researchers and policymakers over the use of hard coastal protection structures or defences. Generally defined as built engineering works designed to abate the physical force of the sea, such structures range in scale from major infrastructure systems in delta cities (Nicholls et al., 2010) to small-scale constructions erected informally on sandy shores (Jonah et al., 2016). Hard defence measures, such as seawalls and groynes, demarcate the land–sea boundary, protecting people and property from erosion and flooding. They can be effective at doing this, at least in the short term. However, in recent years, their long-term sustainability has increasingly been called into question. Engineered protection structures installed along the shoreline require maintenance, which can be costly to undertake (Donner and Webber, 2014). Their ability to prevent beach loss has also been questioned by geologists, who have demonstrated that built defences often deflect problems of erosion further along the coastline (Brown and Barton, 2013). Importantly, growing reliance on hard protection structures in many parts of the world risks lowering shoreline 'capacity to adjust and adapt to climate-related ocean change', especially in small island states (Magnan and Duvat, 2020: 5). This is because such structures lock coastal communities into pathways in which ever-greater control over the sea is sought but which are ecologically harmful and increase future risk of catastrophic failure (Cooper and Pile, 2014).

Despite these issues, questions of how hard coastal protection structures are devised and come into being, as well as the various social effects that they produce, have not been a research priority in the environmental social sciences and humanities. To date, much work in this vein, at least in Western scholarship, has been grounded in modernist explanations concerning the twin projects of the domination of nature and nation building (Paterson, 2001). According to these projects, the separation of ordered, human culture on the land from the wildness of the sea is crucial to the expansion of, and claims to, national territory. For example, in a classic, historical study, Schama (1987) explored how, following independence in the late 16th century, the construction of Dutch national identity as a people chosen by God provided a rationale for claiming large swathes of land from the sea. However, while important in revealing the power and origins of modernist coastal management discourses, such accounts focus on the ideological foundations of controlling land and sea, saying less about the everyday material encounters, events and practices that defence structures enable as well as the social relations that such objects influence and shape. This underplays the significance of sea defences to the making and unmaking of individual lives in coastal communities, as well as the potential for community-based action, mobilisation and agency in relation to such structures (Amin, 2014). There is a need, then, when considering ways of developing political and practical engagements with more sustainable coastal management activities to make these material connections and effects more 'explicit and accountable' (Gesing, 2021: 208).

The aim of this paper is to address these themes. Through empirical research on a small island in the Maldives, the paper moves the examination of coastal defence measures from their ideological origins into the realm of the material, towards 'narratives of lived practice and engagement' (Anderson and Wylie, 2009: 325). It does this from two overlapping but distinct theoretical perspectives where new materialism thinking has been especially prolific in recent years: those of human–nature relations and the built environment. These perspectives demonstrate that human control over the world is only ever partial and that seemingly stable objects, as part of a larger arrangement of multiple, contingently performed set of interactions and feedbacks, are often prone to breakdown, collapse or dismantlement, what Larsen and Christensen (2015) refer to as 'unbecoming'. Moreover, such objects, when in the right combinations with other physical and physiological bodies, have 'thing-power' (Bennett, 2010), possessing the vitality and capacity to

produce effects that exceed human intentionality and contribute to wider natural-cultural practices. In these ways, the paper demonstrates not only the challenges that island-based coastal communities face in exerting control over the unruly sea but also how defence structures participate in the formation and shaping of social relations within and between communities as part of this process. Coastal defence measures, it is argued, are ends in themselves, in terms of their significance as particular forms of material culture, in addition to their more recognised function, as a means to prevent erosion and flooding (Jackson, 2000).

These ideas are particularly relevant to the Maldives, a timely and important case study that exemplifies the challenges faced by many small island states currently experiencing rapid economic and environmental change. The Maldives is an archipelagic nation located in the Indian Ocean made up of around 1200 small islands arranged into twenty coral atolls. Of these islands, 185 are 'inhabited' and a further 130 are luxury resorts. The country's population is approximately 450,000 people, with half living in the capital city of Malé. Income from high-end tourism is the mainstay of the national economy, with many Maldivians having jobs in this sector. However, despite the country being positioned in the 'high human development' category by the UNDP (2020), the Maldives faces a series of economic, political and environmental challenges, including climate change (Malatesta and di Friedberg, 2017). Domestically, coastal erosion is recognised as one of the main environmental problems that the country faces. Hard coastal protection structures were first built on islands as early as the 1970s but they began to proliferate in the 1990s (Naylor, 2015). As a result, concerns have been raised by scientists that many Maldivian islands 'now exhibit an altered-to-annihilated capacity to respond to ocean-climate pressures' over the medium to long-term (Duvat and Magnan, 2019: 1). To investigate these issues, a series of six visits to a small, inhabited island was undertaken between 2015 and 2021 during which residents shared their perceptions of how and why the land–sea boundary is changing, the impacts of these changes, and how such impacts are managed. These visits allowed insights into non-human vitality, emergent agency, and the thing-power of coastal protection structures to transpire.

This paper is organised as follows. The next section begins by introducing how fundamental ideas concerning coastline management have shifted in recent decades before considering what a new materialist perspective offers in terms of how the land–sea interface and hard coastal defence structures are understood. The third section further sets the scene by describing the problem of coastal erosion in the Maldives and the ways in which central government and island-based communities have responded to this challenge. The fourth section presents the findings from the island where the empirical data collection took place, exploring its changing coastline and how this has set the stage for the development of a new, community-organised coastal protection 'mega-project'. Through interviews, observation and secondary data sources, the section examines how the island's sea defence measures act not just as a means for demarcating the land–sea boundary but also as an active participant in community efforts to harness technical know-how about shoreline dynamics, imagine and create an island future, and engage in collective action. The final section concludes by reflecting upon the vitality that inheres in the non-human world and the thing-power of hard coastal protection measures. While acknowledging that such measures can be ecologically problematic, it argues that they also play a role in social transformation. On the island, coastal defences are not only involved in beach protection; their own unique material complexities mean that they are also engaged in the practice of island future-making.

Coastal protection and the new materialism

In recent decades, ideas surrounding coastline management have changed considerably. Conventionally, the practice of demarcating the land from the sea has been congruent with the notion of modernity, the long-established Western view that humans are separate from, and

doing things to, the non-human world (Castree, 2005). According to this view, coastal managers use technology to exert agency over an indifferent nature, moulding land or seascape according to human designs and purposes (Benson, 2019). Indeed, as Paterson (2001: 67) states, 'The image of sea defences is perhaps one of the clearest images of the human domination of nature. The physical control of one of nature's most powerful forces, water, exemplifies the project of mastery in symbolic terms as much as anything.' Sea defences, then, are tools for human progress made subservient to human will, a technical project of supremacy over nature undertaken with little regard for pre-existing communities or traditions. From this perspective, the standardised, stable forms of structures such as seawalls, groynes, revetments and breakwaters are outcomes of the rational process of planning and design, not easily 'complicated by ecological, cultural, or social factors' (Linton, 2010: 8). Where these structures do fail then this is usually attributed to deficits in local implementation (Betzold and Mohamed, 2017). On Pacific Islands, for example, Nunn (2009) explains that hard defences frequently wear away and collapse due to rudimentary construction techniques. Local institutions, lacking in support from central government, are often not 'capable of adequate planning, hydrodynamic analysis, maintenance, monitoring or sourcing of construction materials and capital' (Donner and Webber, 2014: 337). As a result, decision-making 'is conditioned largely by instinctive responses' or is part of local custom and practice (Nunn, 2009: 218).

These ideas are powerful and have endured for hundreds of years. However, they have been modified in the past few decades by a holistic, systems-based approach to coastal management, which emerged out of environmentalism in the 1970s and, more recently, in recognition of the Anthropocene, or humanity's entwinedness with, and impact on, the natural world (Crutzen, 2002). This new way of thinking acknowledges the complexity of physical processes along the shoreline and the difficulties involved in exerting control over this space. It indicates that the coast is not a permanent line to be drawn on a map; it is a dynamic environment in which land and sea are in constant interaction with one another through sediment erosion and accretion. Hard sea defences, once erected, often worsen the problem of 'coastal squeeze', whereby beaches become 'trapped between erosion and rising sea level on the wet side and encroaching development from expanding human populations on land' (Defeo et al., 2009: 8). This suggests, in turn, that the correct approach to coastal management is one that promotes flexibility along the land–sea interface, incorporating 'soft', nature-based defences centred on habitat restoration (Morris et al., 2020). These aim to make room for the sea through coastal accommodation or retreat rather than attempting to 'hold the line' (Gibbs, 2016).

This new approach, promoting an ethic of 'working with nature' rather than 'against it', points towards a more cautionary, less hubristic way of managing the coastline in which the limits of human agency are recognised. Nonetheless, such an approach is still, as Paterson (2001: 72) noted, based on a discourse of domination, albeit 'a subtler one than simply using brute force'. In other words, it still maintains the society-nature distinction, although with greater awareness of, and sensitivity towards, the non-human side. In contrast, new materialism offers a more fundamental challenge to modernity's long-held ideas. According to this more radical ontology, rather than being deterministic and mechanistic, matter is indeterminate and in-the-making, emerging from, and existing in, turbulent webs of relations constituted by complex gatherings and distributions of things (Deleuze, 1992). In contrast to the usual 'interaction', which assumes that there are separate individual agencies that exist in advance of their coming together, new materialism introduces the notion of 'intra-action', 'which recognizes that distinct agencies do not precede, but rather emerge through, their relational, mutual entanglement' (Barad, 2006: 33). Humans are embedded in this process, 'always in composition with nonhumanity, never outside of a sticky web of connections or an ecology' (Bennett, 2004: 365). Agency, the capacity to cause effect, is thus dispersed across the livingness of the material world, sometimes in collaboration with the intentions of

humans and at other times in competition to ensure its own performance (Power, 2005). This raises, in turn, the prospect of 'multinaturalism', hybrid communities of different configurations of human–non-human spaces (Latour, 2007) that are 'alive with the creative potential of endless evolutions and innovations' (Kearnes, 2006: 67).

Such insights suggest that coastlines are not passive land or seascapes moulded by human intent but rather natural-cultural entities in which particular configurations of the social and the material intra-act as part of the ongoing becomingness of the world (Gesing, 2017). The coastline, to use the words of Latour (2005: 128), does not 'just sit there', 'untroubled and untroubling, waiting impassively for us' to intervene (Whatmore, 2003: 92). Rather, it resists 'its incorporation into particular political-economic and spatial forms' (Braun, 2008: 668), pushing back against the plans of coastal managers, who find that they must compete with non-human forces, such as sea currents, when attempting to enrol the unruly shoreline into their plans (Callon, 1986). Moreover, sea defences, instead of being the solid, obstinate structures as is commonly assumed, are part of this larger arrangement of multiple agencies, intra-actions and feedbacks. In other words, protection structures are objects of 'ontological instability' (Braun, 2008: 677), contingently performed through the complex, unstable relationships between bodies, things and people, and thus prone to breakdown, collapse or dismantlement. This is often recognised by people living in coastal communities, who understand that sea defences are impermanent and require ongoing maintenance (Fincher et al., 2014).

New materialism insights, then, can do much to animate the unpredictability, vibrancy and intractability of the non-human world. However, there is more that can be said about the productive capacities of hard coastal defences themselves to make things happen, to perform as 'vivid entities not entirely reducible to the contexts in which (human) subjects set them' (Bennett, 2010: 30) and to be given 'their due as an active participant in the world's becoming, in its ongoing intra-activity' (Barad, 2006: 136). One area of scholarship that has helped reveal these forms of agency in recent years is that of the built environment, which has advanced understanding of the urban social in two significant ways. First, scholars have shown how human-made structures are able to 'actively participate in often unexpected ways, in the processes by which political relations are articulated and enacted' (Harvey and Knox, 2012: 524). According to Silver (2014: 790), such performative infrastructures are often located between 'formally planned infrastructure, authorised and built by the state' and 'informal infrastructures that are in-the-making, provisional, and often temporary'. These are spaces of improvisation and experimentation in which communities struggle to cumulatively develop the scientific knowledge necessary to control spatial and social landscapes, and out of which 'some expressions of space production are criminalised while others are legitimised and the population is disciplined' (Ortiz and Boano, 2018: 193). These ideas, for example, have informed Gesing's (2017) ethnographic work, who uses the example of a dispute between a local council and residents over a seawall in New Zealand to show how the visibility and materiality of large coastal structures are becoming enrolled into future coastal protection policy.

Second, scholars have demonstrated how urban structures not only 'shape human action in intended ways but also refract and send ripples through the possibilities of discursive interpretation and representation of social life' (Harvey and Knox, 2012: 524). In other words, such structures possess poetic potential, enabling 'experiences and perceptions, transforming imaginations and forwarding powerful desires and dreams' (Wakefield, 2018: 3), evoking 'enthusiasm of the imagination' (Mrazek, 2002: 166) and enabling people to feel 'what it is to be modern, mutable, and progressive' (Larkin, 2013: 337). These affects are especially potent when the future appears uncertain, providing a lifeline to an imagined future or foreclosing what is possible and producing feelings of abjection (Moran, 2009). For example, Yarina and Takemoto (2017) examined how the visibility of engineered coastal defence structures in Tuvalu raised the status of those settlements

that had been protected and provided governments and aid agencies with evidence that measures were being undertaken to protect people from sea level rise. In these ways, the feelings of safety and security that hard defence structures can evoke have the potential to change the ways that coastal communities think and see the world, moving from a 'living with risk' approach to one that attempts to eliminate sea flooding altogether (Cooper and Pile, 2014).

Overall, new materialism thinking shifts attention from the traditional focus on human manipulation of the physical environment towards a more holistic examination of the power of the non-human world to also shape and influence human action and thought. As outlined above, exploring these dynamics in relation to coastline management can help reveal the multifarious ways in which the objects of hard coastal protection approaches are continually involved in the production of islands and the communities that live on them. The aim of the next section is to explore these ideas in the context of the Maldives.

Coastal protection in the Maldives

The physical environment of the Maldives is highly dynamic, continually changing on a range of timescales. There are two main monsoonal seasons, the northeast *Iruvai*, which produces drier, calmer weather from December to February, and the southwest *Hulhangu*, which produces the rainy season and rougher conditions at sea from May to September. The Indian Ocean's strong currents shift with the prevailing monsoonal conditions. There are also weaker tidal currents, which flow according to the height of the semidiurnal tides and the direction of the prevailing wind, and short-run episodic events, such as storms and tsunamis (McLean and Kench, 2015). Island position, size and shape are continuously adjusting in response to these forces, as the sand and coral rubble that make up the land are deposited or washed away. These processes result in net gain or loss of shoreline in different seasons but with overall island size being maintained as beaches shift from one side to another or sandbanks disappear only to emerge again the following season in a different location.

Historically, populations living on these 'moving islands' were considered mobile. Houses and outbuildings traditionally built from coconut fronds, coir rope and wood were easily disassembled and moved to another location further away from the encroaching sea or to a different island. This complicated efforts by the national authorities to define which islands were inhabited and which were not (Maniku, 1990). However, mobility began to lessen in the early 1970s when the mechanisation of tuna fishing increased household incomes, resulting in communities adopting more durable, static homes made of coral, sand and limestone (Mohamed, 2016). This trend accelerated following the introduction of luxury tourism onto resort islands in the late 1970s. Following the 2004 Indian Ocean tsunami, government policy briefly focussed on mass population resettlement and consolidation, although this proved to be politically unpopular (Kothari, 2014). Present-day policy, in contrast, is focussed on supporting island communities in place through the dispersal of infrastructure and services throughout the archipelago. Local development priorities usually centre on harbour construction and land reclamation. Moreover, the 'democratisation' of the tourism sector in 2009, which for the first time allowed international tourists to stay in local guesthouses on inhabited islands, resulted in a construction boom, and further urbanisation, on many islands (Cowburn et al., 2018).

These changes, while producing rapid economic development, have also led to sediment starvation on many island shores (Duvat and Magnan, 2019). This has, in turn, accelerated coastal erosion in many locations, posing problems for populations increasingly fixed in place. Problematic beach erosion was first observed on inhabited islands in the late 1970s and 1980s, being highlighted in the country's 1985 National Development Plan (NDP). The phenomenon was attributed at the time to the construction sector, leading to local bans on coral and sand mining, followed by the introduction

of national legislation in the 1980s and 1990s. Despite these measures, however, beach erosion has consistently been reported as the most significant environmental problem in the Maldives in a range of national and strategic development plans to date. Beach erosion categorised by government as 'severe' is observable today on most inhabited islands, where properties have been damaged by the sea or are threatened by inundation. This is especially the case on western-facing shores, which are exposed to the powerful *Hulhangu* monsoon.

These problems have led to the development of hard coastal protection measures on nearly all inhabited islands (Sovacool, 2011). A high diversity of structures is observable today, including seawalls, breakwaters, revetments and groynes, made from materials such as coral, sand, cement and stone. Growing populations and the need for space mean that there is limited scope to implement retreat-based adaptation strategies. Many planning measures, such as 20-metre setbacks from the coastline, are not considered realistic where demand for housing is present. Moreover, the construction of engineered coastal defences replicates the development model in Malé, which is by far the nation's wealthiest island (Naylor, 2015). Island councils, which are locally elected on a three-yearly basis, are aware that the capital city was relatively unaffected by the 2004 tsunami due to the large defensive barrier that encircles it. Leaders on islands threatened by erosion and flooding are under pressure to demonstrate results and the visibility of engineered structures provides reassurance that measures to protect people and property are being undertaken.

In accordance with these priorities, the Fourth NDP released in 1994 recommended the development of hard coastal protection works on inhabited islands. Nonetheless, government rhetoric has begun to shift towards the promotion of 'nature-based' or 'living' protection measures in recent years. For example, the country's 2019 Strategic Action Plan (SAP) calls for the preservation of coral reefs and coastal vegetation on all inhabited islands as a way of protecting coastlines. These measures are considered advantageous as they have 'the ability to self-repair after storm events and adapt to changes in climate, reducing maintenance costs compared to traditional defence structures that will need to be redesigned (for example, rebuilt, reinforced and raised in height)' (Morris et al., 2020: 486). Nonetheless, nearly all island communities remain committed to the development of hard coastal defences, often attempting to erect structures by themselves if central government support is unavailable. Historically, small-scale, ad hoc installations have not required formal consent. However, in recent years, island councils have been required to follow the formal Environmental Impact Assessment (EIA) process, which is implemented by the Environmental Protection Agency (EPA) under the Ministry of the Environment (MoE). The MoE has the authority to terminate any coastal defence project that it determines as having an undesirable effect on the environment.

To examine these issues, empirical research was carried out on an inhabited island located in North Malé Atoll about 40 min speedboat ride from Malé. The island is 1 km in length and 200 m wide at its broadest point, with an overall area of approximately 18 hectares. Its population is about 1200 people, an increase from around 700 in the early 1980s. Two hundred and fifty metres to the north of the island is an international resort. The lagoon situated on the island's western side and the open ocean to the east are characterised by strong tides and currents that shift with the changing of the monsoons. The island's beach systems are highly dynamic and move back and forth on a seasonal basis, altering the island's shape over the course of the year. This mechanism is referred to locally as *vodey fas* or 'moveable earth'. There are also longer-term changes taking place, especially on the island's western shore, where sand is being removed by ocean currents but not washed back again, leading to chronic erosion problems. Various efforts to suppress or control the movement of sand over the past few decades have resulted in many sections of the island's coastline being subject to some form of hard modification.

The island has increased dramatically in size since the 1980s. Today, it is 40–50% larger than it was 30 years ago due to land reclamation in its eastern and north-western coastal zones. Land

reclamation is strongly supported by island residents due to the extra space that it creates for housing. The addition of a harbour on top of the reef in 1995 further extended the island eastwards. A channel, which runs through the lagoon separating the island and the resort, was cut into the seabed to allow easy passage of boats and a four-hectare industrial zone was built on the harbour's eastern side. These changes have been accompanied by the rapid expansion of the built environment. Residents recall that much of the island used to be covered by dense woodland, called *vaa*. Today, however, most of the *vaa* has been cleared to make way for housing, with only a small section of forest remaining on the island's southern side. A major factor in the expansion of the built environment has been the growth of the local tourism industry. There are presently 11 guesthouses operating on the island, with another six under construction, and numerous cafés and restaurants.

As stated in the first section of this paper, a series of six visits to the island was undertaken between 2015 and 2021, each visit of 1–2 weeks in duration. During these visits, the aim was to 'get to know' the island's coastline and sea defences. Thirty semi-structured interviews were conducted with island residents, including members of the island council, guesthouse managers, and members of women's community groups. A wide variety of residents was sampled so that the main intersectional differences present on the island, such as age and gender, would be represented by the data. In addition, five walking interviews (Evans and Jones, 2011) with small groups of men and women were undertaken around the island's perimeter. These walks allowed observation of the main changes to the coastline that had taken place, opening new lines of enquiry (Kusenbach, 2003). In addition, views on coastal erosion and protection in the Maldives were gathered during 13 interviews with coastal engineers, development planners and environmental consultants based in Malé. These individuals either worked for government ministries and agencies or commercial consultancies. Finally, 30 government reports were collected and reviewed to generate background information on environmental change, beach erosion and coastal protection. These included nine National and Strategic Development Plans dating back to 1985. In this paper, names of people and places have been changed to preserve the anonymity of respondents.

Modernising the island: Destabilising and restabilising the land–sea interface

In this section of the paper, the various ideas established above are explored through the presentation and discussion of the empirical data. The next subsection examines the island's land–sea boundary, exploring the causes and effects of problematic beach erosion to date and the ways in which islanders have tried to control the unruly sea in response. Then, the second subsection examines the thing-power of the island's hard coastal protection measures. Focussing on its new coastal defence 'mega-project', the subsection argues that such defences are more than illustrative of the limits of human control; they also play a key role in the formation of social phenomena on the island.

Making and unmaking coastal defences

As explained in the third section of this paper, sand moves on the island in both a cyclical and longer-term manner. *Vodey fas*, the back and forth, rhythmic circulation of sand, is most evident on the island's northern and southern sides, where the tourist beaches are located. This movement can cause concern among tourism managers as it complicates the siting of facilities such as beachside cafés and storage for water sports equipment, which are generally placed by the best sections of beach. However, *vodey fas* does not present a major threat to existing infrastructure or financial investments in these areas and so the sand is generally left to its own devices. Moreover, tourism managers

are reluctant to intervene with hard coastal structures on tourist beaches as these measures might detract from the shoreline aesthetic. In other parts of the island though, most notably on its western and eastern shorelines, more enduring processes of erosion are occurring. This is especially evident on the more densely populated western side where chronic coastal squeeze is occurring between the sea and the road that runs parallel to the *thundi* or beach. In the late 1970s, the beach in this area was between 10 and 20 m wide. Today, however, it has almost disappeared, with most of the vegetation gone and the remaining palm trees collapsing into the sea. One resident, Arifa, who grew up beside the western beach, recalled, 'In the past, this side of the island had a very nice, large sandy beach. It was very beautiful. We used to come to play here as children. But now it is filled with rubble and rocks and the sand has disappeared.' The retreat of the beach also means that the deep lagoon or *vilu*, which used to be close to the shoreline, is now located further out to sea. Thus, Arifa went on to say,'When I was a young girl, my mother used to warn me not to go too far into the water when I went to the beach to wash the pots and pans. She said the lagoon was close to the shore and was deep. Now, the deeper areas of the lagoon are much further from the island. The shoreline has receded so much.' These changes are also of concern to the guesthouse managers whose establishments line the western shore and whose businesses depend on offering a wide, attractive beach to tourists. As one manager commented, 'With no beach we have no tourists, and without tourists there is no income for the island.'

Because of this erosion, many people living close to the western shore are worried that they will eventually have to leave the island. One resident, called Ahmed, explained, 'Our land is at a point on the island that is getting eroded. One corner of the plot next to ours has already been affected. When the property was leased by the council, the plot was described as inland. But now it is right on the sea. It is very concerning, thinking that we might have to leave.' In addition, the erosion is worsening the problem of sea flooding on the island's western side. In this area, flooding has long been a regular occurrence during the southwestern monsoon when storm swells and strong winds cause seawater to breach the beach ridge. However, the floods have increased in frequency and severity in recent years. One incident in June 2020 proved to be particularly serious, when two hectares of land was under water for a week, up to one foot in depth in some places. Most of the houses in the affected area were flooded and the local school was temporarily closed.

As Defeo et al. (2009) pointed out, the causes of chronic beach erosion are often difficult to determine, and this is the case on the island's western side. There is consensus among residents that the island's sand is moving differently to how it used to. Beach erosion on the western shore occurred in the past, but the sand would eventually cycle back again, like on the northern and southern sides. Now, however, sand is becoming completely lost. The most common explanation for this is that the harbour has disrupted the circulation of sea currents around the island, causing sand to be deflected into the open ocean rather than deposited back onto the western shoreline. As Mohamed, a guesthouse worker, explained, 'There is a seasonal rhythm to the movement of sand. It comes and goes. But the harbour has disrupted this pattern.' Another common explanation for chronic beach erosion is sand mining, which supplies material for local construction projects. There are presently five boats on the island that mine sand from an area 200 m into the lagoon, and some residents believe that this activity is starving the western beach of sediment. Additionally, closer to the shoreline, the island council claims that beach replenishment by the nearby resort has contributed to local erosion problems. The resort regularly pumps the sand that accumulates in the channel between its island and the inhabited island onto its southern beach. A member of the island council stated that this is removing sand that would otherwise be deposited onto their own island's western shoreline:

> "We believe that sand pumping by the resort in the channel is contributing to the erosion. Earlier there was so much sand that even the lagoon was too shallow for fishing boats to enter. The council had to deepen the area twice a year. Now most of this soil is eroded away… We estimate that the resort beach has been expanded by about 100 feet in the last ten years whereas we are losing our [western] beach."

As Gesing (2019: 155) states, coastal protection structures are 'only the visible tip of the iceberg of a larger and always socionatural network that may or may not stabilise'. Thus, while the parts of the shoreline characterised by *vodey fas* are mostly left alone, the building of hard defence structures in areas where longer-term beach erosion has occurred is indicative of a widespread and concerted effort to secure the coastline. This construction has taken place within the formal–informal interface of urban development, with some expressions of space production becoming legitimised and others disallowed. The seawalls that surround the harbour and industrial zone, which are made from rock armour, were installed by the state-owned Maldives Transport and Construction Company (MTCC). In other areas of the coastline, however, construction has been more informal in nature, undertaken by the island council, guesthouse managers and homeowners. In many locations, coastal armouring has occurred using sand-filled jumbo bags, concrete-filled oil drums, rock boulders and waste rubble from construction activities. On the island's western side, sandbags have been laid down and the ridge between the top of the beach and the coastal road has been raised to mitigate flooding. Many of these informal structures, however, are only semi-permanent, eventually degrading and being washed away by the ocean's waves and currents. The sandbags, for example, often require replacement and the artificial ridge needs constant maintenance.

In general, these coastal protection measures are accepted by island residents as necessary despite their limited effectiveness. Far more controversial, however, was the building of three 'homemade' groynes by two guesthouses in front of their properties along the island's western shore. These structures projected around 5 m into the lagoon and had circular platforms installed at their ends to act as dining areas for tourists. They were made of sandbags topped with a layer of concrete and cost between 30,000 and 40,000 Rufiyaa ($2000 and $2500 USD) each to erect. The groynes were built without the permission of the island council and without an EIA from the government, although their construction was not prevented. As the island council explained shortly after their building:

> "There are no EIAs done but the council does not feel right to stop them from putting the groynes. The guesthouses said, if a property owner is facing erosion and their land is getting slowly eroded, he would try to prevent this and act. So when they are doing things to protect their land how can the council say you have to stop and do an EIA? EIAs are so expensive and not affordable by everyday communities."

While the groynes protected the area of beach in front of the guesthouses, they accelerated erosion along the island's northern section. Niuma, who lives beside the worst affected area, explained, 'The *boashi* tree on the beach near our house fell into the sea due to erosion after the groyne was built by the guesthouse.' In response, residents contacted the island council in Malé to complain about the groynes, arguing that they had been built without authorisation. Photographs of the groynes were taken and sent to the EPA as evidence. As a result, the EPA contacted the island council and ordered the groynes to be dismantled. Initially, the guesthouses only partially complied with this order, removing the outer, circular platforms and digging a tunnel under the groynes so that the sea current was able to move past them. However, the June 2020 storm severely undermined one of the two partially dismantled structures, causing large cracks to appear on its side and gouging a hole underneath its base. This resulted in further complaints to the island council with the outcome that the structures were eventually fully demolished by the guesthouse owners. Today, just the remnants of the groynes remain on the beach, these traces being further broken down by the actions of the waves, currents and winds, especially during the *Hulhangu* season. Crabs and other small animals burrow into the dismantled groynes, dislodging small quantities of matter as they do so, and seaweeds grow on the groynes' exteriors, their roots penetrating and further breaking down the leftover substrate. In their own small ways, then, these plants and animals also contribute to the dismantlement of the groynes.

These accounts demonstrate how attempts to fix the land–sea boundary through hard coastal protection measures can cause or accelerate erosion in other areas. They also show how defence structures, as ontologically unstable objects, are unmade by both human and non-human actors as relations between people and the physical environment change. And yet, despite these shortcomings, the island council is planning a much larger-scale coastal protection scheme consisting of 20 groynes built around the entire perimeter of the island and sand pumping to replenish the most severely eroded sections of beach. The project's EIA received approval from the EPA in 2019 and the council is now seeking to raise the funds necessary to begin the works. The scheme, described by one council member as a 'mega-project', is a considerable step-up in ambition, scale and cost from earlier coastal protection works. It also represents a move from an informal development approach to one that is positioned in the official sphere of EPA approval. This does not mean, however, that the new project is completely formalised. For example, the very high cost of conducting an EIA with a MoE-authorised consultant meant that it was necessary to hire a 'friend' of a council member to carry out the surveying work at a reduced rate.

The new megaproject provides further evidence that the island's coastal system is becoming locked into a hard development pathway in which residents seek ever more control over the unruly sea. This, however, is not the only effect of the coastal protection project as its positioning at the formal–informal interface suggests the potential for a high degree of material performativity (Ortiz and Boano, 2018). Indeed, as the next subsection in this paper demonstrates, the new groynes and beaches being developed are involved in the formation of various social phenomena on the island, including the harnessing of technical expertise, future-making and collective action.

Coastal defences and social transformation

On the island, hard coastal protection structures, rather than being passive objects, appear to have 'captured' the attention of islanders, who related their extensive efforts to accumulate technical know-how on the design, construction and effects of sea defences. This has largely been a practice-based process, islanders using whatever means they have at their disposal locally, while remaining receptive to external advice and expertise. The original groynes that were built and then dismantled on the island's western side were based on designs used on Maafushi Island, which is located some 25 km south of Malé. Maafushi is well known in the Maldives as a pioneer in local tourism, with 44 guesthouses presently in operation. Much of Maafushi's coastline has been reinforced with rock armour, and groynes have been installed on the island's northern shore to create and stabilise a tourist beach. These modifications have resulted in an informal coastal protection 'blueprint', an approach to shoreline defence emulated by other islands seeking to establish their own local tourism industries. In addition, on the case study island, informal input into the design of the original groynes was provided by a Maldivian engineer based in Malé, who stayed in a local guesthouse in 2018. As the island council explained: 'There was a popular consultant who was drawing and giving ideas for groynes… Yeah, he told us what it should be built like. He stayed in this guesthouse and gave ideas.' The suggestions from the consultant were incorporated during the groynes' construction phase. To save on labour costs, the groynes were built by a small team of labourers assembled by the guesthouses, with each structure taking around 2 days to complete.

Despite the inputs from the consultant, the island council admits that it made mistakes in the design and construction of the original groynes, thus exacerbating the unruliness of the land–sea boundary. One problem was that the structures, pieced together from locally available materials, were impermeable to water. This overly restricted the sea current moving along the western shore, exacerbating beach loss along other sections of shoreline. The shape of the original groynes was also wrong; they were built too high and too flat, further hindering the movement

of seawater. In the new project, the island council intends to follow EPA guidelines on groyne construction. Advice is also being provided by an established Maldivian engineering company, which is the owner of the island's largest guesthouse. The new groynes will be built from 100- to 300-kilogram rock boulders laid on a layer of rubble and sand, which provides the construction with stability. The boulders will, according to the project's EIA, 'allow some water movement through them via small voids within the structure'. The new groynes will not be flat but gently sloping from the beach into the water. As one council member explained, 'The sloping is important so that the waves can move from one side to the other.' Moreover, the role of beach replenishment in coastal protection is now better understood on the island. One guesthouse manager explained that, when laying new groynes, it is important to replenish the beach in between the structures at the same time to minimise erosion in other areas of the coastline. This was overlooked when the original groynes were built because the priority was to protect the existing areas of beach immediately in front of guesthouses. The new project, however, will construct 15 m of beach along 1400 m of the island's coastline. This new beach will rise 1.2 m from mean sea level to the vegetation line and will require 15,000m^3 of sand to complete. The sand will be dredged from the seabed near the island and pumped onto the shoreline.

The new project, then, as stated above, represents a move from an informal to more formalised sphere of activity by the island council in which in-the-making and provisional coastal protection structures are replaced by ones that are officially planned and authorised. The accumulation of technical knowledge associated with this shift is raising the profile and status of the island council in the eyes of the community. As one long-term island resident, called Leela, stated, 'The council has been working hard for us on the groynes project. We used to make them ourselves, but these fell apart. Now we can make better groynes that protect the island.' Moreover, the new groynes and beaches are not only enrolling islanders into their performance through the promise of a stabilised land–sea boundary but are also causing islanders to be aspirational. Transforming the island into a major tourist hub in a manner like Maafushi is at the centre of these aspirations. Indeed, because of the new project, many islanders now envisage a future in which the island is dominated by tourist guesthouses, shops and cafés. For example, one woman, Shifa, who sells souvenirs to tourists, stated,

> "With the new groynes and beach coming we are starting to feel serious about the future. There will be more and more guesthouses and tourists every year. In ten years we will be mostly guesthouses. In the past it was not possible to have a building more than two storeys, but they are getting higher. One [building] is even ten storeys. Eventually we will look like Malé. Our whole shoreline will be protected."

Although concerns exist among many islanders that Western tourism is contrary to local Islamic culture, these changes are, in general, widely supported. Guesthouse tourism provides the best salaries on the island and allows people to live and work locally rather than move away to a resort island. Tourism is also a way for the island to be more self-reliant, providing it with the means to modernise by helping to fund infrastructure development projects for energy, water and sewerage.

In recognition of these benefits, the new project is not only intended to fix the land–sea boundary but is also stimulating appreciation of the island's potential for tourism. According to the project's EIA, the new, replenished beaches, in addition to stabilising the shoreline, will attract investors and international tourists to the island. At first glance, this way of shaping the island's perimeter can be seen as an indicator of human domination of the physical environment, a means of creating the visual display of the 'island paradise'. However, this control is only ever partial. For example, the pumped sand that results from beach reclamation is coarser and darker and therefore less desirable than the fine, white sand that characterises *vodey fas*, but which is more elusive. As one council member stated, 'We would prefer the finer sand, but we have no way of pumping this from the seabed. We

are unable to capture it.' Moreover, the new project will create new swimming areas in the sea. At present, these are limited due to the shallowness of the island's lagoon and reef. The project, however, envisages the creation of two dredge areas for beach replenishment, one positioned off the island's southeast shoreline and a second to the southwest. The seabed in these two areas, which is presently 0.6–0.8 m below mean sea level and with dense seagrass, will be reshaped so that it is deeper and with a gentle slope moving away from the shoreline, making it more suitable for bathing. In these ways, as stated in the project's EIA, 'the island economy will greatly benefit from additional beach and swimming areas'. However, it is also acknowledged by island residents that these underwater features will require ongoing maintenance. In other words, they will draw the community into a relationship of competition with the sea currents and waves that continuously threaten to fill the swimming areas with drifting sand, thus disrupting human plans. As an EIA consultant based in Malé commented, 'It is not uncommon to see these kinds of underwater sandscaping activities in impact assessment plans. They are included to increase the value of the project, but they also require dredging every year and this is not always considered'.

While the new coastal protection measures have the power to invoke the aspirations and imaginations of islanders, their high construction costs are a significant barrier to the realisation of the project. Under the country's decentralisation laws, island councils can charge a fee for the services that they provide, such as provision of electricity, water and sewerage. The government is also obliged to provide councils with a portion of the state budget and councils may seek loans from banks or international financial institutions. However, the quantities of funds raised from these sources are relatively modest (Naeem, 2019). In addition, while councils are meant to work cooperatively as part of an atoll-based administrative structure, in practice islands often compete to attract financial investment. On the case study island, there is a widespread feeling among residents that coastal protection is the responsibility of central government and that the island council could do more to attract funding for coastal defence structures. To illustrate, Hawwa, who is a long-term resident of the island, stated: 'It is true that the council have become knowledgeable about sea defences. But I feel that they could do more to bring the issue to the attention of the national government. We need the government to support us'. The island council has written directly to the MoE and the EPA several times requesting financial support. They also filmed the June 2020 flooding incident, sending one copy to the MoE and posting a second onto the island's Facebook page. However, to date, these efforts have been to no significant avail.

Despite these setbacks, the new coastal protection measures are deeply implicated in novel forms of cooperation that are emerging on the island, and thus in the experience of community action and solidarity. Historically, although the council has been supportive of the island's burgeoning guesthouse sector, there has been little official collaboration between the two parties, the latter group being dominated by Malé-based individuals and companies and thus viewed as 'outsiders' by the local leadership. The beach and groynes, however, rather than just 'sitting there', awaiting the agency of human intention, are actively bringing these stakeholders together in new ways of working that otherwise would have not existed. As one council member explained, to build, shape and maintain the shoreline, 'It is necessary to get contributions from everyone, contributions from seniors on the island, from MPs, we need the cooperation from everyone. The island council cannot spend solely on the groynes'. Local guesthouses are central to this effort. Under plans developed by a specially formed island committee, each guesthouse is responsible for funding and constructing one to three of the twenty new groynes depending on their location. As a guesthouse manager stated, 'The groynes are the most important part of this project, and we are coming together and coordinating to see them built. This is a new way of working for us'. Under the arrangements, guesthouses will also contribute to a central fund to hire a sand pump for the beach replenishment phase of the project. Each establishment is expected to contribute an amount depending upon its size and capacity to pay.

Conclusion

As stated at the outset of this paper, hard coastal defence structures can be effective in protecting people and property from erosion and flooding, at least in the short term. This is evident in the Maldives where coastal defences are frequently favoured by communities whose land and financial assets are threatened by encroachment from the sea. However, as also stated above, there is quite often uncertainty over how the unruly sea and the structures designed to control it will intra-act with each other and with the wider physical and social environment at different points in time. Hard coastal defences, such as groynes and seawalls, although seemingly stable and obdurate, possess their own distinct, material complexity that can result in their unbecoming and eventual removal. In other words, hard sea defences are part of an ecology 'in the sense that [they are] an interconnected series of parts, but…not a fixed order of parts, for the order is always being reworked in accordance with a certain "freedom of choice" being exercised by its actants' (Bennett, 2010: 97). In the case study island, this reworking is most evident via the actions of the sea and wind, the different building materials that make up the defensive structures, the small-scale actions of the animals and plants that inhabit them, and the observations, concerns and activities of island residents. Of all these, human intervention to remove the groynes following the order from the Maldives EPA provided the strongest effect in deconstructing the recently erected sea defences. However, various non-human actants were also involved in this process, especially the sea in altering the flow of sand along the island's shoreline following the building of the groynes. For these reasons, hard coastal defences, despite their apparent solidity, are as much characterised by instability as steadiness, by complexity as technical simplicity, both in terms of their internal material structure and their interactions with the wider physical environment. Such defences can be stabilised to some extent, but, as objects always in-the-making, this will inevitably be an ongoing project.

This non-human liveliness means that the familiar Western-based distinction between 'subject' and 'object', 'human' and 'sea defence', becomes somewhat blurred when considered through a new materialism lens. As demonstrated on the case study island, coastal protection structures are more than passive tools, subject to the physical forces of the ocean and weather and subservient to human mastery; they are also entwined and implicated in the ongoing production of the island and people's lives on it in various ways. As shown in the fourth section of this paper, the structures are acting as a basis for the accumulation of technical know-how, thus raising the status of the island council and its popularity among residents. They are allowing the island population to establish an aspirational vision for the future and take directed action towards realising that vision (Green et al., 2012). The sea defences are also stimulating collective action, as they work with the island council and guesthouses to realise the new coastal protection 'mega-project'. As such, sea defences have a thing-power of their own, actively bearing upon, and participating in, various social phenomena in addition to causing unforeseen and unintended effects on the physical environment. Of course, in preserving the island's culture and protecting the human endeavours taking place upon it, the island's coastal structures have no conscious motive or intention to produce such outcomes (Callon, 1986). Nonetheless, they are engaged in thing-based work alongside island residents to achieve these results. As such, to use the words of Bennett (2010: 98), 'we must posit a certain non-human agency as the condition of possibility of human agency'.

These complexities highlight the limits to human agency in attempting to demarcate the land–sea interface, raising questions about how to respond to the liveliness of things that are often beyond human cognition and control. At first sight, such complexities appear to lend support to the notion of moving away from the use of hard, engineered coastal defence systems towards softer, more flexible and more adaptable 'nature-based' solutions, both in the Maldives and further afield. This movement is in line with other studies that have emphasised the unpredictability of the non-human world and the consequent need to 'live with' or 'make way' for nature rather

than attempt to control it (Head and Atchison, 2015). However, these complexities also suggest the need to promote or implement such a transition with care. As indicated above, new materialism perspectives reject nature-culture dichotomies, positing instead that we live in a multinatural world (Lorimer, 2012). This multinaturalism is also the case in the Maldives where, despite frequent references to an essentialised Maldivian 'natural beauty' by the tourism industry, different versions of nature are evident, including those constructed for the benefit of international tourists (Kothari and Arnall, 2017). Care is therefore required to not attempt the replacement of one all-encompassing vision (i.e. 'modern') with another (i.e. 'natural') and instead acknowledge the possibility of speculative island futures that do not foreclose inventive life (Braun, 2008). In other words, rather than being imprinted from outside by experts claiming absolute reason (Latour, 2007), island futures can be practiced with their own particular configurations of human and non-human spaces as suits local conditions, and in ways that accord with local ideas of what is environmentally desirable and just (Yaka, 2019). This alternative approach recognises the limitations of hard coastal protection structures but also understands that these are doing more than simply affecting the physical environment; their own unique material complexities mean that they are also productively entwined in creating open island futures.

Highlights

- Conventional modernist explanations downplay the roles of coastal protection structures in the making and unmaking of island communities.
- Hard sea defences, such as groynes and seawalls, are part of a human–non-human ecology and possess their own thing-power.
- Such defences participate in the formation of various social phenomena in island communities, including future-making and collective action.
- As structures with their own material complexities, hard coastal protection measures are entwined in the production of multinatural island futures.

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References

Amin A (2014) Lively infrastructure. *Theory, Culture and Society* 31: 137–161.

Anderson B and Wylie J (2009) On geography and materiality. *Environment and Planning A* 41: 318–335.
Barad K (2006) *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham, USA: Duke University Press.
Bennett J (2004) The force of things: Steps to an ecology of matter. *Political Theory* 32: 365.
Bennett J (2010) *Vibrant Matter: A Political Ecology of Things*. London: Duke University Press.
Benson MH (2019) New materialism: An ontology for the Anthropocene. *Natural Resources Journal* 59: 251–280.
Betzold C and Mohamed I (2017) Seawalls as a response to coastal erosion and flooding: A case study from Grande Comore, Comoros (West Indian Ocean). *Regional Environmental Change* 17: 1077–1087.
Braun B (2008) Environmental issues: Inventive life. *Progress in Human Geography* 32: 667–679.
Brown S and Barton ME (2013) Shoreline response of eroding soft cliffs due to hard defences. *Maritime Engineering* 167: 3–14.
Callon M (1986) Some elements of a sociology of translation: Domestication of the scallops and fishermen of St. Brieuc Bay. In: Law J (ed.) *Power, Action and Belief. A New Sociology of Knowledge*. London: Routledge, pp. 196–233.
Castree N (2005) *Nature*. Oxford: Routledge.
Cooper JAG and Pile J (2014) The adaptation-resistance spectrum: A classification of contemporary adaptation approaches to climate-related coastal change. *Ocean & Coastal Management* 94: 90–98.
Cowburn B, Moritz C, Birrell C, et al. (2018) Can luxury and environmental sustainability co-exist? Assessing the environmental impact of resort tourism on coral reefs in the Maldives. *Ocean and Coastal Management* 158: 120–127.
Crutzen P (2002) Geology of mankind. *Nature* 415: 23.
Defeo O, McLachlan A, Schoeman DS, et al. (2009) Threats to sandy beach ecosystems: A review. *Estuarine, Coastal and Shelf Science* 81: 1–12.
Deleuze G (1992) *The Fold: Leibniz and the Baroque*. Minneapolis: University of Minnesota Press.
Donner SD and Webber S (2014) Obstacles to climate change adaptation decisions: A case study of sea-level rise and coastal protection measures in Kiribati. *Sustainability Science* 9: 331–345.
Duvat V and Magnan AK (2019) Rapid human-driven undermining of atoll island capacity to adjust to ocean climate-related pressures. *Scientific Reports* 9: 1–16.
Evans J and Jones P (2011) The walking interview: Methodology, mobility and place. *Applied Geography* 31: 849–858.
Fincher R, Barnett J, Graham S, et al. (2014) Time stories: Making sense of futures in anticipation of sea-level rise. *Geoforum; Journal of Physical, Human, and Regional Geosciences* 56: 201–210.
Gesing F (2017) Whose beach, which nature? Coproducing coastal naturecultures and erosion control in Aotearoa New Zealand. In: Dürr E and Pascht A (eds) *Environmental Transformations and Cultural Responses: Ontologies, Discourses, and Practices in Oceania*. New York: Palgrave Macmillan, pp. 125–156.
Gesing F (2019) The politics of artificial dunes: Sustainable coastal protection measures and contested socio-natural objects. *DIE ERDE: Journal of the Geographical Society of Berlin* 150: 145–157.
Gesing F (2021) Towards a more-than-human political ecology of coastal protection: Coast care practices in Aotearoa New Zealand. *Environment and Planning E: Nature and Space* 4: 208–229.
Gibbs MT (2016) Why is coastal retreat so hard to implement? Understanding the political risk of coastal adaptation pathways. *Ocean & Coastal Management* 130: 107–114.
Green M, Kothari U, Mercer C, et al. (2012) Saving, spending, and future-making: Time, discipline, and money in development. *Environment and Planning A* 44: 1641–1656.
Harvey P and Knox H (2012) The enchantments of infrastructure. *Mobilities* 7: 521–536.
Head L and Atchison J (2015) Governing invasive plants: Policy and practice in managing the Gamba grass (Andropogon gayanus) - Bushfire nexus in Northern Australia. *Land Use Policy* 47: 225–234.
Jackson P (2000) Rematerializing social and cultural geography. *Social & Cultural Geography* 1: 9–14.
Jonah FE, Mensah EA, Edziyie RE, et al. (2016) Coastal erosion in Ghana: Causes, policies, and management. *Coastal Management* 44: 116–130.
Kearnes M (2006) Chaos and control: Nanotechnology and the politics of emergence. *Paragraph* 29: 57–80.

Kothari U (2014) Climate change and migration: A political discourse of resettlement in the Maldives. *The Geographical Journal* 180: 130–140.

Kothari U and Arnall A (2017) Contestation over an island imaginary landscape: The management and maintenance of touristic nature. *Environment and Planning A* 49: 980–998.

Kusenbach M (2003) Street phenomenology: The go-along as ethnographic research tool. *Ethnography* 4: 455–485.

Larkin B (2013) The politics and poetics of infrastructure. *Annual Review of Anthropology* 42: 327–343.

Larsen J and Christensen MD (2015) The unstable lives of bicycles: The 'unbecoming' of design objects. *Environment and Planning A* 47: 922–938.

Latour B (2005) *Reassembling the Social: An Introduction to Actor-Network-Theory*. New York: Oxford University Press.

Latour B (2007) *Politics of Nature: How to Bring the Sciences into Democracy*. Massachusetts, USA: Harvard University Press.

Linton J (2010) *What Is Water? The History of a Modern Abstraction*. Vancouver, Canada: UBC Press.

Lorimer J (2012) Multinatural geographies for the Anthropocene. *Progress in Human Geography* 36: 593–612.

Magnan D and Duvat V (2020) Towards adaptation pathways for atoll islands. Insights from the Maldives. *Regional Environmental Change* 20: 1–19.

Malatesta S and di Friedberg MS (2017) Environmental policy and climate change vulnerability in the Maldives: From the 'lexicon of risk' to social response to change. *Island Studies Journal* 12: 53–70.

Maniku HA (1990) *Changes in the Topography of the Maldives*. Malé: Forum of Writers on Environment (Maldives).

McLean R and Kench P (2015) Destruction or persistence of coral atoll islands in the face of 20th and 21st century sea-level rise? *Wiley Interdisciplinary Reviews - Climate Change* 6: 445–463.

Mohamed M (2016) Historical changes in human-nature interactions in island communities of the Maldives. *Rural South Asian Studies* 1: 22–36.

Moran J (2009) *On Roads*. London: Profile.

Morris RL, Boxshall A and Swearer SE (2020) Climate-resilient coasts require diverse defence solutions. *Nature Climate Change* 10: 482–490.

Mrazek R (2002) *Engineers of Happy Land: Technology and Nationalism in a Colony*. Princeton, NJ: Princeton University Press.

Naeem AH (2019) *Review of the Decentralization Framework in the Maldives*. Malé: Transparency Maldives.

Naylor AK (2015) Island morphology, reef resources, and development paths in the Maldives. *Progress in Physical Geography* 39: 728–749.

Nicholls RJ, Brown S, Hanson S, et al. (2010) Economics of coastal zone adaptation to climate change. *World Bank Discussion Paper 10, Development and Climate Change Series*. Washington DC: The World Bank, pp. 1–44.

Nunn PD (2009) Responding to the challenges of climate change in the Pacific Islands: Management and technological imperatives. *Climate Research* 40: 211–231.

Ortiz C and Boano C (2018) Medellin: Performative infrastructures – Medellin's governmental technologies of informality – the case of the encircled garden project in Comuna 8. In: Rocco R and van Ballegooijen J (eds) *The Routledge Handbook on Informal Urbanization*. New York: Routledge, pp. 193–203.

Paterson M (2001) *Understanding Global Environmental Politics*. Hampshire, UK: Palgrave.

Power ER (2005) Human-nature relations in suburban gardens. *Australian Geographer* 36: 39–53.

Schama S (1987) *The Embarrassment of Riches*. London: Collins.

Silver J (2014) Incremental infrastructures: Material improvisation and social collaboration across postcolonial Accra. *Urban Geography* 35: 788–804.

Sovacool BK (2011) Hard and soft paths for climate change adaptation. *Climate Policy* 11: 1177–1183.

UNDP (2020) *World Development Report*. New York: United Nations Development Programme.

Wakefield S (2018) Infrastructures of liberal life: From modernity and progress to resilience and ruins. *Geography Compass* 12: 1–14.

Whatmore S (2003) Generating materials. In: Pryke M, Rose G and Whatmore S (eds) *Using Social Theory: Thinking Through Research*. London: Sage, pp. 89–104.

Yaka O (2019) Rethinking justice: Struggles for environmental commons and the notion of socio-ecological justice. *Antipode* 51: 353–372.

Yarina E and Takemoto S (2017) Interrupted atolls: Riskscapes and edge imaginaries in Tuvalu. *The Plan Journal* 2: 461–495.