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Article

Peripheral: Resilient Hydrological Infrastructures

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Abstract: This article addresses the issue of developing designs of resilient hydrological infrastructures for cities facing sea level rise in the Anthropocene. It undertakes short case studies of differently scaled cities, three in the Global North and three in the Global South. The aim is to investigate the current water management situations in order to reveal potentials for increased urban and environmental resilience. Cities are approached as complex adaptive systems (CAS) negotiating uncertainty that concerns designing for resilience, understood as viable transitions for their interlinked social, ecological, and technological systems (SETS). The main finding is that, despite obvious differences, the six cases are surprisingly similar. Potentials for increased hydrological resilience reside in design approaches that work differently with what is currently deprivileged and considered 'merely' peripheral. Peripheral cities and the peripheries of coastal cities are found to be of key rather than minor adaptive infrastructural import. To reprivilege the peripheral here means to adopt more dynamically flexible, long-term, decentralized, and nonanthropocentric urban design approaches to water and infrastructures. Specifically, this article advocates thinking about water via at least four critical displacements. These displacements point toward alternatives concerning excessively static and land-based designs, short-term planning, overly anthropocentric conceptions of the city environment distinction, and undue centrism in planetary urbanization of the Global North and Global South. In conclusion, this article presents a brief outlook to other cases which suggest that greater resilience potentials are likely to be found in planning for the complexly ecotone city. This works mostly bottom-up from the local regimes for water sensitive infrastructures to regional network designs that can engage with larger climatic and ecological landscapes.

Keywords: urban–environmental infrastructure; urban periphery; urban design; rising sea levels; resilience; adaptive planning; ecotone cities

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1. Introduction

Current research and practical urban design and planning make clear that ongoing climate changes involve kinds of disruptions in the hydrological Earth system regime in the Holocene which many current urban infrastructures are not capable in managing [1–6]. It is now much less frequently disputed that anthropogenic forcings are at play in current and future changes in the water cycle, affecting the entire distribution and movement of water on, below, and above the Earth's surface, and that this increasingly has consequences for human urbanization. Already in this century, sea level rise is known to pose major risks to most coasts and therefore to 750 million to 1 billion people, constituting two-thirds of the world's major cities and many more smaller cities located in low-lying coastal areas. It is also well known that major challenges are being posed to urban infrastructural design by present and notably future flooding, permanent inundation, erosion, higher storm surges, and saltwater intrusion. This is especially so in an epoch which is also experiencing massive increases in human coastal populations and economies, with the most significant rise in urbanization taking place in Africa and Southeast Asia. Urban design will be one critical driver in human responses to sea level rise and perhaps to anthropogenically forced climate change more generally. Highly interesting and promising research is very evidently on the rise in this area in attempts to point towards more sustainable and more water-sensitive cities [7–14].

In this context, this article addresses unresolved issues relating to infrastructural design meeting SLR. It starts from the assumption that infrastructural urban design responses are adaptive attempts to answer wicked problems [15–17]. This means that there is no infrastructural 'solution' in a purposeful reductionist sense but rather uncertain and more or less complex ways of trying to live with the problem. Staying with the trouble of SLR would take place via more or less uncertain adaptations, i.e., without a certain 'solution' as an end-point. The key unresolved and still controversial research issue can be stated quite briefly. How can one observe the hydrological challenges in existing city-environment situations and then go on to implement changes in urban infrastructural designs that can be considered transitions to more resiliently water-sensitive cities?

1.1. Open Systems Approach: CAS and SETS

The sections below assume that answers to this question are best sought by adopting a complex adaptive systems (CAS) approach. This involves working with social–ecological, ecological–technical, and social–technical transitions and relations (SETS). This article adds to the relatively recent complexity turn in urban design and planning. This is gradually becoming more theoretically and methodologically refined as well as more operational, even if this is not yet the major paradigm in design and planning practice, governance, and policy [18–25]. Such an approach typically operates with an open systems notion whose expansion permits acknowledgement, perhaps also a better practical handling, of observable blind spots concerning the relations and processes at stake. For example, the open systems approach adopted here can observe that a significant portion of existing research and most existing management of coastal urban design processes that address SLR tend to be hampered by a strong path-dependency on modern scientific reductionism. Continued adherence to this in design management tends to maintain barriers against recognition of a number of the complex interconnections and co-dependencies in social–ecological–technological systems. This article adopts an open systems approach that may point to blind spots qua undue reductions of relations with the complexity in environmental processes (biological, ecological, and material).

1.2. Decentering the Human City

In this open systems approach, key focus is placed on negotiating environmental and human urban cultural resilience. A working assumption is that transitions towards increased hydrological resilience means making adaptive designs that negotiate the strong tensions between environmental hydrological sustainability goals and human demands to manage water for continued urban existence and (de)growth. The article is staying with the unresolved tensions between human and 'more-than-human' urbanizations hidden in this 'and'. Here, 'more-than-human' is not used in a strong posthumanist sense nor does it signal the kinds of ontological turn found in new materialisms and speculative realisms. It is rather taken in a broad ecological sense as a signal of co-dwelling and co-developing with other beings and entities. It is also considered a counter-point to culture–nature dualisms and undue anthropocentrism.

It is very difficult to work with disloyalty towards one's own species, even if it is only partial. It is difficult to navigate a passage across the tensions and barriers that tend to appear for human citizens (including the poor, homeless, home owners, designers, planners, engineers, and governance and policy representatives) when the limits of the human-centric city are put into question. The article engages with this via relatively low-key oscillations between weak anthropological and more nonanthropocentric angles of approach. Such decentering works via multiple displacements and takes the time of all working through Moreover, anthropocentrism is a formidable potential and a barrier to adaptation. A more-than-human approach here includes recognition that in many contexts there are very good reasons for having central regard for the welfare of humans, and that this is often an inevitable position to be taken. This article thus includes a certain care for the human city and its anthropogenic operations, but it also insistently introduces a set of critical environmentalist hints. These amount to granting a little more voice to more biocentric and ecocentric concerns. Such hints try to announce that resilience is still primarily to be found by engaging environmental processes with another relationality. Resilience potentials notably reside in meeting biospheric, ecosystemic, and physicochemical processes as vital infrastructural co-designers operating in their own right. Hydrological design projects would do well by assuming from the outset that human-oriented infrastructural parts of a city unfold in a wider and more complex environment on which they co-depend and in which they are embedded as peripheral.

In other words, this article inclines towards the more-than-human city. It is also more oceanic and cryospheric in perspective. It is less terrestrially anchored than the mostly freshwater-oriented research which looks at human engineering of infrastructures that affect the flows from streams, rivers, rains, and groundwaters. The focus here is rather on how ecological–technological domain developments do or do not make viable a wider social–ecological hydrological resilience.

1.3. Infrastructures

When addressing 'infrastructures', the assumption is that transitions towards increased urban resilience requires deep structural change. The approach in this article draws on recent insights from a recent transdisciplinary infrastructural turn. One of the richest recent anthologies was edited by Anand, Gupta, and Appel [26]. This collection offers a very interesting attempt to address infrastructures as both material and discursive, straddling the metaphorical and materially real. It is perhaps particularly useful in its engagement with a postcolonial struggle against notions of infrastructure deriving from a liberal, anthropocentric modernity. This includes critical observations of this modernity, both its use of infrastructures as territorially expansive and exappropriative and its infrastructuring of the timescales to control compressions, expansions, and speeds. This collection is quite adept at pointing to infrastructures constructed to implement uneven water politics as well as inequities in the infrapolitical timing of water distribution, notably in the Global South. A very good overview of diverse approaches in the infrastructural turn can be found in the work undertaken by Addie and others [27].

'Infrastructure' does mean but not only means the material and technical internal frame for the circulatory system of the human city inherited from 19th Century industrialization. This is typically thought to involve the nuts, bolts, pipes, scaffolding, wire, and concrete of streets, roads, sewers, transport systems, gas, potable water, and electricity, along with various public services. The term as used here is also not limited to the networks of the urban sociality and culture [28], the territoriality and geopolitics [29–31], and the economy [32–35] that enable the everyday processes of human life and affectivity in the city [36–38]. Rather, 'infrastructures' are key elements generative of urbanization in its multiple variants, quite different and sometimes quite similar in the Global South and the Global North. 'Infrastructure' as an enabling condition has a more expanded meaning. This co-involves ecology and the environment alongside the human society and urban ecotechnics [39–41]. As metabolic mediation of multiple systemic rifts, 'infrastructures' cut across the inner and outer membrane of the human city to mesh with other material, energetic, biotic, and zoological flows. Water is shared more or less evenly among all of these.

1.4. Peripheralizing Existing Centrisms

This article assumes that pinpointing potentials for increased urban and environmental resilience is best done by situated observations of existing infrastructures with a view to immanent criticism. This means looking for resilience potentials that are hidden in, or immanent to, existing mitigating and adaptive approaches. An important subissue here is to inquire into such potentials by cutting across water-management designs in central, inner peripheral, peripheral, and ultraperipheral human coastal cities that are facing SLR. The objective here is to observe potentials for increased resilience once the different environmental and social capabilities among such cities are observed. The article seeks to highlight sociocultural, technological, politicoeconomic, and environmental similarities and differences.

This line of inquiry brings increased attention to strengths and weaknesses in the hegemonic centrist approaches to resilience in an epoch of planetary urbanization [42–46]. It may seem given that capitals, world cities, and central cities in both hemispheres have by far more of the social, organizational, technological, political, and not least economic resources. They would thus be the agents of change, those capable in fostering the niche developments that open adaptive pathways towards greater resilience. The greater resources residing here is in one sense a factual difference. However, it may also be a blind spot hiding the more resilient approaches. The article notably begins to highlight the ambiguous status of the urban periphery. The peripheral is on the one hand the more or less unrecognized locus of the greatest weakness of urban resilience. At the same time, however, it is also the locus of the greatest resilience potential, in an expanded environmental sense. Here, the article is in general agreement with Filion, Keil, Addie, and others who note that the urban perimeter is where the demand for new infrastructure is strongest and also where its tensions, risks, and implications are most acutely at stake [27,47].

The sections below include claims that resilience potentials reside primarily in the periphery. The sections surprisingly pinpoint shared potentials in this respect across the Global South/Global North and center/periphery divides despite the obvious differences also at play. This is a case study observation, but it is also something supported by a general theoretical insight from transition theories. Key social, technical, and ecological infrastructural transitions are likely to emerge from immanent peripheries, i.e., from changing niches relating to their environments. The article draws on selected urban studies sources investigating the strong de facto center–periphery inequality in city-centric approaches during planetary urbanization [27,42,48–50]. This is used to argue in favor of pursuing the actualization of infrastructural resilience potentials by problematizing the city-centric approach and by managing local, contextually embedded urban CAS. The niche relations of CAS to future urban environments with increased resilience may have to connect bottom-up to contribute to a different kind of networked regional planning oriented primarily by climatic and ecological landscapes rather than by the dominant geopolitical borders drawn by nation-states and 20th Century legislation [48,51–55].

1.5. Resilience, Water-Sensitivity

'Resilience' is currently hypostatized as an ideal in existing research and remains polysemantic and diversely defined, not unlike 'sustainability.' It this article, the term is primarily used with reference to the body of recent research that departs from the early anthropocentric implications in the definition of sustainability [56] as well as from early, more homeostatic notions of resilience. The term is not so much associated with robustness or the capability of rebounding from perturbation to return to equilibrium in a systemic landscape whose regimes are oriented towards a single attractor. 'Resilience' is instead used with a wider reference across the systems in Earth system science to more uncertain, dynamic, longer-term flexibility in a complex adaptive sense. It is thus considerably closer to the notion of nonbrittleness qua graceful extensibility when surprise events challenge existing boundaries. It is close to the notion of a whole set of systemic network architectures that can maintain the ability to adapt to future surprises as climatic and environmental conditions evolve [57–71].

Such an expanded approach would grant the insight that hydrological resilience potential resides in the infrastructural urban *periphery*. The infrastructural issue is always the lasting and flexible drawings, erasures, and redrawings of the city's delimiting membrane between inner and outer flows of the wet and the dry. Infrastructures are always about the longer-term adaptivity of the urban systemic peripheral distinctions between city and environment. These are distinctions maintained or not in an extremely complex, metastable, and sensitively porous urban membrane. It cuts across an inner urban milieu and an outer or associated milieu, or what we tend to call the urban niche in the greater environment. An infrastructure is a complex peripheral membrane seeing to draughts and rising temperatures affecting territories, buildings, and bodies. It is also one that sees to water from the sea and streams, fog, rain and snow from above, and freshwater primarily from below, which likewise affect territories and bodies. An increase in resilience generally remains a potential hiding in the distinctions that existing urban infrastructures draw upon. These are more or less silently calling for different ways of distinguishing hydrological flows and ebbs.

Temporally speaking, the observation would be that potentials for increased resilience lurk in the periphery of the present states of infrastructures. This may concern more or less forgotten potentials residing in past modes of infrastructuring the systemic settlement–environment distinctions. Numerous good examples can be seen in the ways in which a variety of indigenous designs resurface today, relocated and forged as modern–premodern urbanizing hybrids. It may also concern unrealized future potentials, most often emerging at the cutting edge of existing modern technical infrastructures. Again, numerous examples exist, as in niche urban design living labs in world cities and capitals, which focus on negotiating ecologically–technologically innovative transition pathways.

2. Materials and Methods

This article describes six relatively short urban case studies (Copenhagen, Dragør, and Birkholm in Denmark; Jakarta, Indonesia; Malé, Maldives; Tarawa, Kiribati). The cities are all coastal cities vulnerable to SLR. They are selected with a view to equity, one half from the Global North and one half from the Global South. The cases include ultraperipheral (Birkholm), inner peripheral (Dragør), and central cities (Malé, Tarawa, Jakarta, Copenhagen), with a very ambiguous status to be accorded to Malé and Tarawa, which are capitals but simultaneously ultraperipheral small island cities in the Global South. The cities selected cover a broad scalar spectrum to enable investigating whether important similarities are cross-scale. They vary from the very small (Birkholm) through the small provincial town (Tarawa, Dragør) to the medium-sized big city (Copenhagen) and the megacity (Jakarta).

The case studies of the three Danish cities draw in part on desktop study but in part also on materials from preliminary field work undertaken on selected coastal cities that are especially vulnerable to SLR. The materials are obtained with a grounded theory approach to urban living labs [72–79]. These are treated as background materials and stem from field visits combined with a short series of interviews and workshops with practitioners in design, planning, engineering, landscape architecture, and architecture as well as governance and policy management. The other main part of the materials, relating to Malé, Tarawa, and Jakarta, stem from desktop studies.

The article generally draws on transition theory as it is used in the study of climate change conducted by the IPCC, and the related turn in urban design and planning from mitigation to emphasizing more adaptive, regenerative, and transformative approaches. It is informed by second-order systems theory and the complexity turn in urban design and planning [18–22,24]. It specifically draws on a notion of the city as a complex adaptive system (CAS) [80–82]. It thus views a city as a system of systems continuously varying in their design managements and operations in order to find viable infrastructural solutions. Approaching hydrological systemic viability, the article is informed by insights from studies of urban metabolism and political ecology and is concerned with the metabolic movements cutting across an inner milieu and an associated milieu (environmental niche) [83–89]. The article is influenced by approaches that link adaptive systemic viability to concerns with sustainability [90,91]. Recognizing that adaptive developments of hydrological urban resilience requires deep infrastructural and processual change in modern and late modern paradigms of urban design, the article is deeply informed by the infrastructural turn in recent research.

3. Results

In general, the results in this article relate to the regional and global situation for SLR developments as predicted probabilistically in the IPCC reports. The figure below illustrates mean sea level rise through time according to three scenarios (Figure 1). This article considers the RCP 8.5. scenario the more relevant, even if this is most likely understating the severity of future developments (not least due to the uncertainty pertaining to Antarctic and Arctic melting). The article does not go into detail concerning the increased frequency of extreme climatic events but notes that these obviously exacerbate the need for adaptative design of coastal cities.

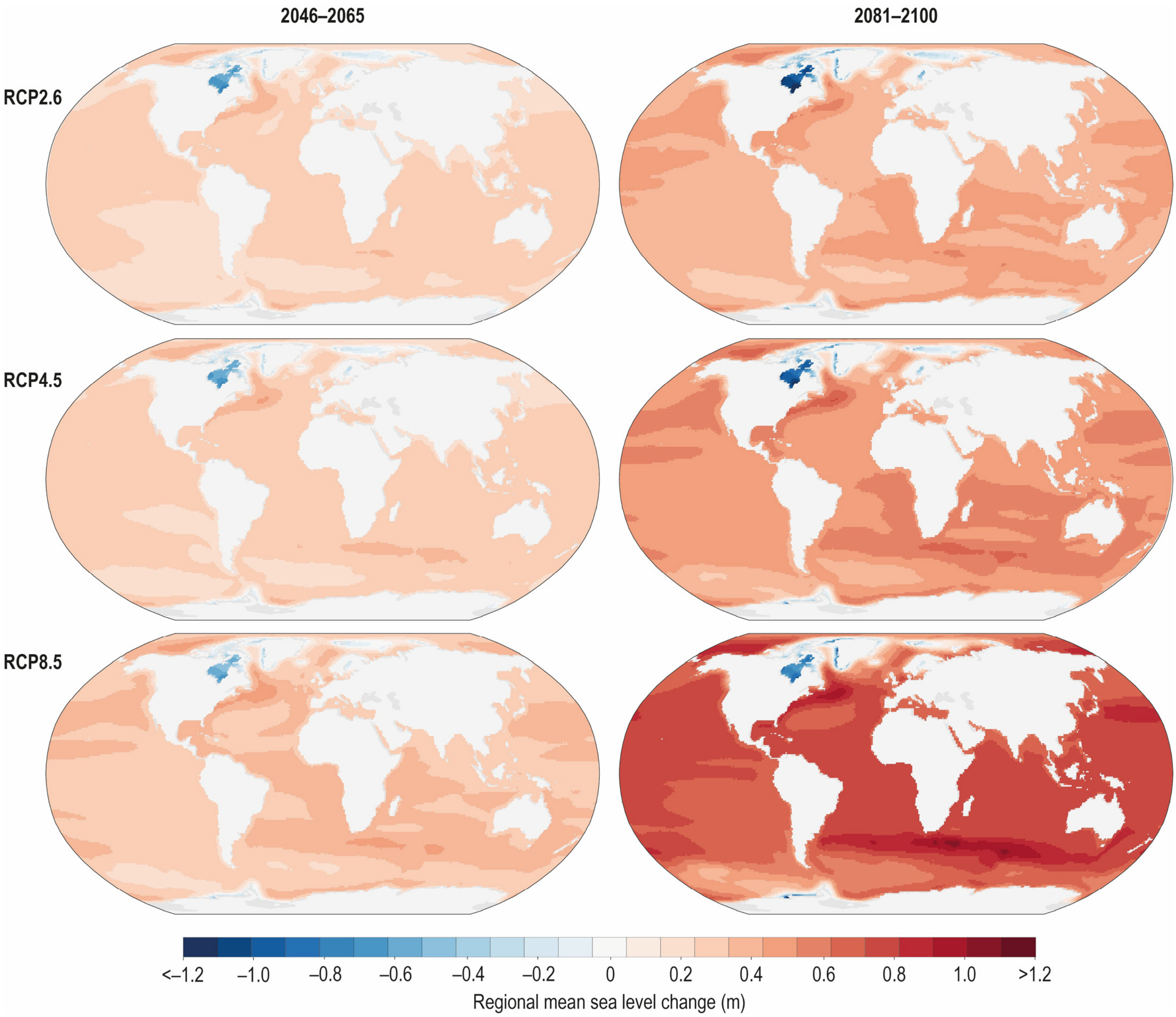


Figure 1. IPCC scenarios for regional mean sea level rise [2].

3.1. Observing the Urban Design States in their Niches, and Future Transition Proposals

The results of the six case studies take the form of observations from a situated co-designer perspective. 'Co-designers' are understood in an expanded sense, including citizens, politicians, governance representatives, business actors, design researchers, but also more-than-human agents. In principle, then, co-designers are also various biotic, ecosystemic, and material agents. However, for the sake of brevity, observations in this article are restricted to those of a biocentrically oriented urban design researcher considering the work on existing local plans and urban design management feedback.

The case studies lead to results on two levels: first-order observation of current infrastructures and the water management situation; second-order observation of design operations and management feedback cycles concerning viable future transitions.

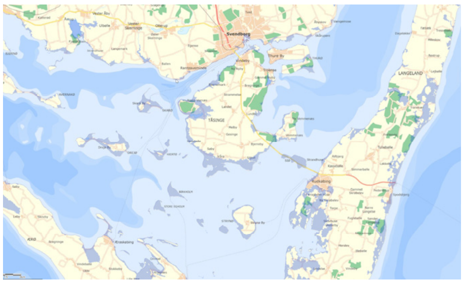
The first series of results consist in short first-order SETS observations of the 'what' of the six cases, i.e., the infrastructural design situation for peripheral resilience for these coastal cities concerning climate change and sea level rise. These observations establish the way for the subsequent observations of the design and water management operations decided upon. These are considered in the light of the mitigating and adaptive pathways accessible for the cities in their different states as ultraperipheral, inner peripheral, or central cities.

When considering the pathways proposed and de facto adopted, each case study operates with a distinction between adaptation and resistance. This distinction is introduced to mark the significant difference between the kinds and degrees of changes at stake, i.e., whether modification of the environment or modification of human urban activities is adopted as a transition pathway. Here, the case studies draw on the work of Cooper and Pile to make clear whether adaption or rather resistance is at stake [92]. Generally speaking, this comes along with the assumption that increased resilience resides with adaptation and, currently, with transition pathways that entail a decreasing impact on environmental processes and relations. Adaptation is at stake in cases which display a high degree of willingness to modify human urbanization activities in response to envisaged SLR, typically involving more or less radical changes in existing land use. Resistance is at stake in cases which demonstrate a choice of design management and planning actions that attempt to maintain the status quo by building or extending defenses against SLR, typically technological engineering 'fixes' such as dikes.

3.1.1. Birkholm

The Baltic Sea regularly flows into the outer wetland areas of this small (92 acres) Danish island located in the South Funen Archipelago. Much of the island is very low-lying, the highest point at the center being 2 m above sea level and major parts being level with the sea. It has no asphalt roads and is today among the most untouched inhabited islands since the predominant agricultural profession was abandoned by the last farmer in the 1990s, and fishing is now less productive but still lucrative for the two remaining fishermen brothers catching shrimp and eel. A few sheep and cows grazing parts of the island laid fallow, and insect- and birdlife have been significantly enriched and diversified during the ecological changes over the last four decades. Birkholm is seeing the gradual removal of most of the last traces of extractive and polluting modern systems, the few exceptions being the daily mail boat and minor summer tourism arriving at the small harbor. Only eight people live all year on the island, forming a small and intensely collaborative community taking care of the houses, the land, and the harbor. During summer periods all 19 buildings are much more likely to be inhabited, the major part being vacation homes. Governmentally, the island and the Birkholm village are part of the Ærø municipality, itself a quite small peripheral island community in Denmark.

Infrastructurally, Birkholm has a hard mitigating approach to SLR. More than 120 years ago a major storm and flooding plus fires led to the construction of stone dikes in two stages. Sea dikes about 1–1.5 m high have been built along the coastline, and a city dike 2.8 m high surrounds the 2100 m perimeter of the little village at the center of the island. Adopting the IPCC RCP 8.5 scenario, which is probably too conservative considering current global emissions and the current research results concerning the pace of melting glaciers in the Arctic and Antarctic, the local environment of Birkholm will see a mean seal level rise of 75–80 cm before 2100, but also more frequent extreme events involving more than 2 m rises and a further increase in mean sea level during the following two centuries at least. In the short term of decades in this century, the current infrastructural design is vulnerable to some erosion of the coast and the lower dikes. While the higher dikes provide considerable mitigation for the village, the already small island is generally likely to see some inundation and changes in inland salinity, especially in its lower northwest area. In the longer term, Birkholm cannot be considered a social-ecologically resilient urban formation if this kind or level of mitigating infrastructural design is used. Further increases than considered in a RCP 8.5 scenario will mean that the island is not resilient concerning land-based urbanization (Figure 2).



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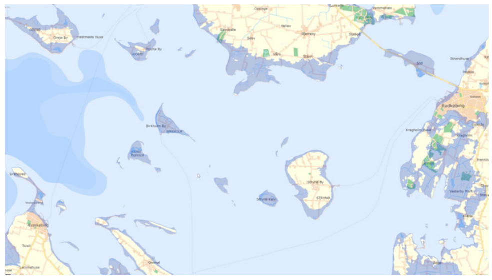


(**B**)

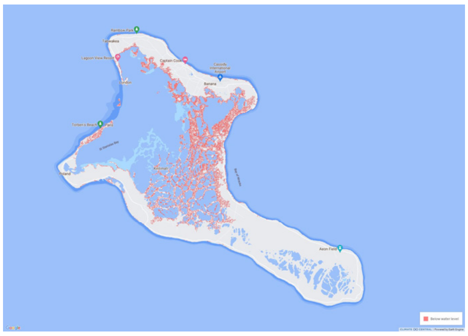
Figure 2. National regional map (**A**) and Birkholm detail (**B**); inundation risk 2120 (blue color), RCP 8.5. scenario [93].

In the ultraperipheral national and regional context for this small Danish village, perhaps a first second-order observation is that no regional or national specific design plan for this island exists, nor is the more local communal municipality of Ærø devoting economical means or feedback in the form of policy and governance support. In recognition of coming SLR, the local eight inhabitants living all year on the island have reallocated some funds from the existing small harbor budget. The transition pathway adopted in this case is a good example of resistance rather than adaptation. The eight people will work on their own trying to raise the coastal dikes and the higher dike surrounding the village. It is notable that only mitigation by way of limited hard protection is considered as a climate change response. A more demanding type of resistance in the form of advance project into the sea and raising the whole island are obviously not on the design agenda. Nor are the inhabitants considering changing the village and its buildings by accommodation. Engaging adaptively in a more recent kind of ecosystem- or nature-based solution around the coastline also appears to be out of reach. In view of the small number of people involved, it is perhaps more surprising that adaption qua planned or managed retreat is not yet explicitly considered a viable pathway to be acted upon, either by the inhabitants, the local municipality, or by the state. This is in keeping with the tendential general blindsiding of this scenario as the difficult last resort, in both research and in design and management practice.

3.1.2. Tarawa

The Micronesian capital of Kiribati, located on the South Tarawa atoll, is low-lying (<3 m) and constitutes a tropical urban island niche surrounded by 500 square kilometers of lagoon, wide open to the ocean and relating intimately to a wide reef. It has very unpredictable rainfall, frequent droughts, and remains extremely vulnerable to climate change in general, and erosion and SLR in particular. The effects of prior floods and ensuing soil salination are already threatening the freshwater supply, which was already limited and strained by urbanization, pollution, excessive pumping, and not least the rapidly growing overpopulation. The urban area is less than 10 square kilometers with few high rises and a high population density (approx. 64,000 people, just above 4900 per square kilometer, or an average of almost 7.5 people per household). The insufficient land use planning, the late modern land reclamations, and the building of some insufficient seawalls as coastal protection infrastructures have had adverse effects on coastal and marine ecosystems, including the mangrove reefs and ironwood trees that otherwise helped protect the land areas, and this process also contributes to the accelerating erosion.

A RCP 8.5 scenario for Tarawa will also be highly likely to include a 2–4 °C rise in temperature during this century, more droughts and tropical storms, and a gradual loss of marine, coastal, and terrestrial biodiversity and ecosystem services. In terms of SLR, Kiribati is expected to be the first country fully submerged, the global 1 to 2 m sea level rise by 2100 and swell waves likely to make it inhabitable (Figure 3).



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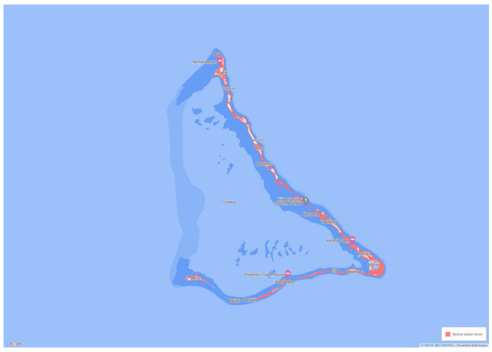


(**B**)

Figure 3. Inundation map (red color), Kiribati (**A**) and Tarawa (**B**) details, 1.5 m SLR [94].

In Kiribati, the design operations and management plans to have Tarawa meet SLR appear poised in an ambiguous manner. They hover between two main scenarios without being entirely decided at this point in time.

The very high confidence that anthropogenic coastal modification, in the form of landfills and land-raising projects, can mitigate SLR effects in the relatively long term makes this one of the two obvious transitional pathways being considered. This would be in alignment with the course already followed. Kiribati's main response so far has been the construction of seawalls along 29% of the coastlines, with rural islands better protected and the semiurban or urban areas such as Tarawa less well protected against SLR [95]. This is counteracted, however, by the lack of adaptive capacity on the nation state level. Kiribati is widely recognized as a least developed country with a small economy and slow growth. Considerable economic funding will be required since most of the land is below 2 m above sea level. Successful adaptation along this path will require international aid. This will put the country into further uncertainty and generate new vulnerabilities, seeing that foreign aid already forms a significant part of the GDP [96].

Hence, the second main scenario derives from ongoing discussions concerning displacement of the population exposed to SLR, i.e., planned retreat and relocation. This scenario acquired increased weight due to consideration of other compounding effects: issues related to population pressures, freshwater security, food security, pollution, and health. Migration has previously been the less accepted option and is still considered difficult and problematic. However, the governmental migration policy measures already proposed under President Anote Tong 2003–2015 is gathering new import. This change in social attitude is partly due to the recent acquisition of a large freehold property, an estate on Vanua Levu in Fiji. Although the area was mainly intended to provide opportunities for economic development and increased food security, Kiribati citizens have increasingly associated it with plans for collective future migration [97]. Some relocation on a smaller scale has previously taken place, but the majority of citizens are still staying in Tarawa and Kiribati, responding by building physical defenses. Today, the same majority indicate that they would migrate given a viable long-term strategy to respond to the future impacts of climate change [98].

This case appears to hover between resistance and adaptation but in fact inclines quite clearly towards the former because the relocation considered operates with the same kind of urban land use. Also, both major developmental design scenarios remain with a strongly anthropocentric focus. The ecological–technological domain for the urban niche of Tarawa is almost exclusively considered by management from the side of the advanced and efficient scientific–technological solution or else the planning discourse shifts to a kind of planned retreat that does not involve a substantial change in urban–environmental relations. The ecological and biophysical domains are mostly blind spots, also with respect to the potential that may reside with nature-based solutions.

3.1.3. Dragør

The Øresund strait and the Baltic Sea continues to be a challenge for the small provincial harbor town of Dragør, founded in the 12th Century as a fishing port located on the coast of low-lying Amager Island, today roughly 12 km from the center of Copenhagen in Denmark. The sea has regularly flooded much of the island, especially the southern part, which is the niche for Dragør, and much of the island is generated and maintained as large land reclamation projects. Since 1900, Dragør has been catastrophically flooded 15 times, most recently in 2017 when both the harbor and a number of the buildings from the 18th and 19th Centuries in the old center of town were under water. Much of the area is environmentally protected by the state and has rich plant- and birdlife along the beaches and in the marshy habitat to the west of the town. The Dragør municipality includes a coastline of 13 km, most of which is low-lying and open to the sea, thus constantly changing along with the waves and the winds. The earlier professions of fishing and agriculture have been superseded by summer tourism and a few local shops and industries, but mostly by a variety of professions since Dragør functions as a near-peripheral suburb tightly linked with the need for a workforce in the larger Copenhagen area and its nearby airport Kastrup.

Governance representatives and the roughly 15.000 citizens are acutely aware that the existing coastal protection, in the form of relatively few and low dikes covering selected parts of the quite long coastline, is inadequate, and that the town is very vulnerable to SLR in the Anthropocene. The area is already threatened by both erosion and flooding, and this high risk situation will become increasingly challenging during the 21st Century. The RCP 8.5 scenario would predict a mean rise of 60 cm, but with an uncertainty between 20 and 130 cm (Figure 4). Storms will occur more frequently, and it is known that a 100-year event will mean inundation for at least 40% of the inhabitants.

During the last five years, the local municipality of this small provincial town, close to the greater, central city of Copenhagen, has worked intensively with participatory design and planning initiatives concerning how to secure coastal protection and make Dragør more resilient. The plan mainly aims at securing the capability to meet what are currently considered 100-year SLR events. After public hearings and a design competition, the town is ready to finalize the plan and start implementation in 2023. The design plan is to be co-financed by the local community, the private company undertaking construction, and the nearby Copenhagen airport. The plan involves coastal protection along six vulnerable coastal stretches and comprises a mixture of responses to SLR. This mixture includes two stretches with a dike as coastal sea wall advance, an early internal reconstruction of the harbor followed by an external advance into the sea, and three stretches with inland dikes.

Dragør is a case in which resistance rather than adaptation is clearly being favored as a response to SLR. The primary concerns in the community, both among citizens, planners, and governance, have remained social and anthropocentric. The designed plan is clearly focused on the ecological–technological engineering of hard mitigating solutions protecting the coast and thus the existing city infrastructure, buildings, and land use. The natural environment and ecological or biophysical processes have been discussed among all involved parties, and the nature reserves close by are clearly valued and respected, but these clearly remain secondary or tertiary concerns in both design operations and management feedback. It is noteworthy that the recent design competition included obviously more adaptive proposals. The design proposals demonstrated the flexibility and long-term potentials in nature-based solutions, but these more complex and more ecologically oriented pathways were clearly not preferred.

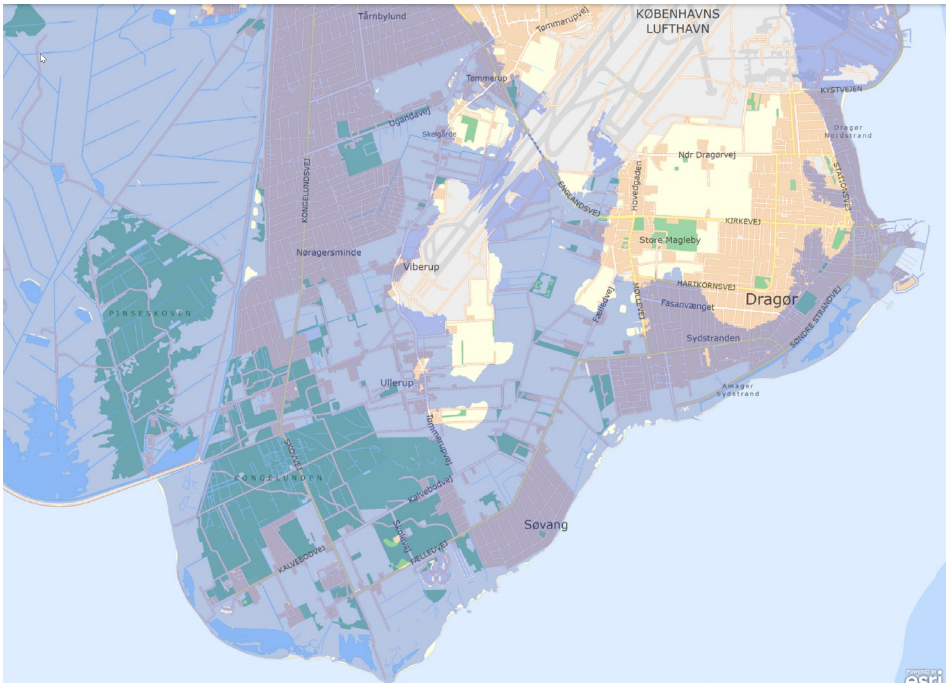
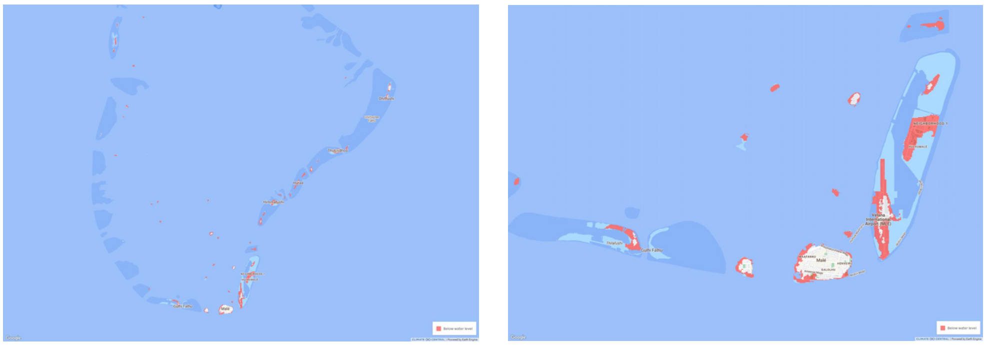


Figure 4. National regional map, Dragør detail; inundation risk 2120 (blue color), RCP 8.5. scenario [93].

3.1.4. Malé

The atoll-based capital of the Maldives with its six interlinked islands is heavily urbanized, especially the central Malé island where the entire landmass is built up so as to leave no traditional countryside and only the ocean as it environmental niche. Older imperial style fortifications and gates are long gone. Tourism as the main economic activity is instead based on late modern urban expansion, including numerous land filling projects into the sea. The ecological–technical infrastructural developments are not sustainable, e.g., fresh water is provided by desalination of brackish water pumped up from 50–60 m deep wells, sewage is pumped directly into the ocean, and solid waste is moved to neighbor islands to serve as lagoon fill (the airport area built on the Hulhulé island fill is a good example). Since 80% of the Maldives remain just 1 m above sea level, Malé's topography as the flattest country on the planet renders it extraordinarily seawater-sensitive. The city of Malé with its quarter million people on just eight flat square kilometers is social-ecologically vulnerable as both one of the most densely populated cities in the world and as a local niche currently maladapted to climate changes.

Relying on a RCP 8.5 scenario, the period until 2050–2100 is highly likely to bring Malé into a situation where the exposure of population, buildings, and infrastructures to multiple climate change hazards will lead to the loss of (human) lives. Fresh groundwater will gradually be reduced by a third, but already today almost 97% of the country no longer has fresh groundwater. A rise of temperatures leading to a single coral bleaching event in 2016 already affected around 60% of the outer perimeter coastal protection for the islands. Moreover, although almost 50% of the BNP is being used to meet climate change challenges, ecosystem services are very likely to have become further weakened by land reclamation and hard seawall coastal protection projects contributing to erosion and reef deterioration elsewhere. Governance reports that more than 90% of the islands already experience severe erosion. Just a 50 cm sea level rise, perhaps generated via one of the relatively rare tropical storms or tsunamis in this area, would entail flooding and potential loss of 80% of the land mass, whereas a 1 m rise (or approx. the mean global sea level rise in 2100) means 85% flooding (Figure 5).



(**A**) (**B**)

Figure 5. Inundation map, Maldives (**A**), Malé (**B**) detail, 1.0 m SLR (red color) [94].

In the Maldives, and in the city of Malé especially, design operations and management plans to meet SLR are left suspended in an ambiguous fashion. During the decades from the 1960s until today, a number of decisions in national politics, treatments in parts of existing research [99], and extensive media coverage of the Maldives as a small island nation under existential threat document that the perception of high risks of irreversible flooding were supposed to be met with a response in the form of planned or managed retreat, i.e., relocation. Relocation policies have been implemented on smaller scales, with greatly varying results (circa 50/50 successful and failed projects). However, these were unfolded mostly as a means of socioeconomic development and a path towards strengthened autonomous island institutionalization, and not primarily as a response to SLR. Rapid urbanization, increased tourism, considerable economic development, strengthened democratic institutions, and broad sociocultural traditions currently form significant barriers against planned retreat proposals. These are also not overtly part of design operations and management policy today. The ambivalence of the developments is the inverse version of the Tarawa case mentioned above. There, partial departure from advancing ecological–technical solutions has led to gradual strengthening of management discourses and public affirmation of planned retreat and relocation.

In Malé, the main focus is instead on two main lines of urban–environmental redesign, although neither of these are yet fully detailed or funded plans. One part of the redesign is more obviously adaptive, involving radical modification of human urbanization activities and land use. The other part of redesign is a continuation of the existing path dependency on resistance. Given that the first part is a smaller and experimental project, Malé must overall be considered to fall on the side of resistance rather than adaptation.

The first developmental line concerns a late modern ecological–technological inventive approach in the form of the development of one of the first floating cities in the world. The project was presented in a UN context as a design modeled in-part on the human brain and in-part on coral patterns. It is under construction and assembly since 2022, just a few miles from Malé, planned and led by Dutch Docklands in the Netherlands [100]. The entire floating city will oscillate with the sea on a pile drilled into the ocean floor. The plans include claims to ecofriendliness and the fulfilling of sustainability goals—via an allegedly 'scarless' ecological–technological relationality. In addition to its unfinished and ecologically untried status, this line of development is not (yet) scaled to deliver a generally socially resilient transition pathway for Malé or the Maldives in general. The second line of redesign development is also already in partial implementation stages and involves combinations of advance land reclamation and land raising. This was already undertaken with landfill construction on Hulhumalé Island, which is raised 2.1 m above sea level, or at least 60 cm higher than existing island formations [101] (p. 393). Land reclamation and land raising are also the transitional pathways suggested as socially feasible and more likely, as noted in parts of recent research [102,103].

Both lines of design management are in uneven, partial development, and both currently are meeting a series of barriers: human sociocultural factors influencing moves, social–political–economic policy challenges, and physical and engineering challenges. Moreover, the Hulhumalé island construction is clearly not ecologically resilient, and both of the major types of redesign proposed do not yet respond to the more-than-human potential adverse impacts of land-advance and artificial island construction in this local marine niche. It is unclear to what extent island construction will include nature-based solutions, e.g., new reefs (a development that has been tried in the Maldives but with unclear results, ecologically speaking). Overall, Malé appears to disregard planned retreat and to decide on a pathway involving technically engineered hard mitigation with some minor adaptive traits, but little in terms of long-term resilient nature-based and deep ecological projects.

3.1.5. Copenhagen

Copenhagen has been an island city since it was founded as a fishing village around 700, and its east side and central parts of the city are low-lying, facing the Øresund strait along the Zealand and Amager island coastlines. It has been expanded multiple times since it became a capital around 1400, not only inland but into the ocean via land reclamation projects. Both fishing and the trade in the modern harbor have ceased as main occupations in parallel with the build-up since the 1800s, especially of this small metropolis spanning roughly 100 square miles for 17 municipalities and a population of 1.4 million (2.2 million in the greater Copenhagen area). The city is the political, economic, social, and cultural center of Denmark and is still experiencing significant urban development, facilitated by massive investment in infrastructure, institutions, and the service sector, including tourism.

Copenhagen has been flooded numerous times in the past, also very recently due to either heavy rainfall or storm surges. The mean sea level will rise according to the same scenario as mentioned above for Dragør, but Copenhagen is also more vulnerable to rain flooding, which will be the dominant risk in the short term. Concerning SLR, RCP 8.5 scenarios demonstrate that the risk of the sea flooding, especially for the central parts of the city on Zealand and Amager islands, is already low today but will move into a high risk within the next five decades (Figure 6). Already in 2060, high tides and storms leading to 180 cm SLR or more is no longer a 100-year event but rather a 20-year event. In effect, at the onset of the 22nd Century, high tides of 226 cm are 20-year events that will flood the entire center of Copenhagen, parts of the city on Amager, and parts of the especially low areas in the southern parts of the city on Zealand. Copenhagen central governance and local municipal governance are very aware of these issues. Along with all other coastal urban municipalities in Denmark, they have been in the process since at least 2015 of developing and agreeing upon urban design plans for climate change and coastal protection.

As the large capital in a developed country in the Global North, Copenhagen has a highly functional urban system and considerable resources to redesign the city with a view towards climate change. The state, the municipality of Copenhagen, and local municipalities have been collaborating for more than 10 years to elaborate revised designs and plans for a more resilient blue-green city, along with companies and a variety of consultancies with experts (environmental specialists, engineers, landscape architects, architects, and more). Design management gives ongoing detailed and expert feedback and feedforward information respecting these plans, both to the public and to the actors involved directly in the design and planning [104–106]. The plans are comprehensive, covering urban redesign developments for three to eight decades ahead with respect to all aspects of climate change. The plan is to be co-funded in a distributive democratic manner, involving all societal layers from the state and private companies through municipalities to the individual citizen.

Figure 6. National regional map, Copenhagen; inundation risk 2120 (blue color), RCP 8.5. scenario [93].

Concerning the hydrological dimension, Copenhagen proposes to undertake a wide range of design operations to change the way in which the city manages water from above (rain and snow), below (groundwater and the sewer system), and from the side (canals, lakes, streams, the ocean). This includes overall blue-greening design operations and management that change streams, lakes, reservoirs, and the entire set of sewers and the hydraulic system for freshwater in the greater Copenhagen area.

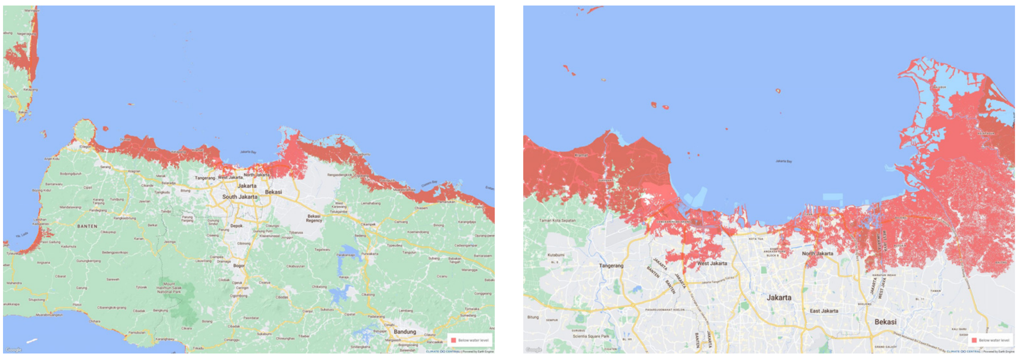
It notably also involves redesign aimed at protecting the city against a DVR90 scenario for high tides, i.e., tidal SLR 255 cm above the normal level. This is a design plan that is also deemed as making good societal and political–economic sense considering the even higher costs associated with severe flooding. The main actions to be taken consist in implementing regional and local plans for a new early warning system for evacuation, building a larger number of dikes (0.5 m to >2.5 m), raising a number of vulnerable roads and tunnels and increasing runoff channels, and raising (future) building elevations. In addition, the plans include the construction of dams with locks at the northern and southern ends of the city harbor. A pilot overall planning initiative on the national level has been ongoing since 2021, aimed at more comprehensive and more long-term resilient design thinking from coast to coast in the country. This includes a storm flood pilot subproject for Copenhagen, which is in its early stages but demonstrates awareness that all major traffic system infrastructures currently are not sufficiently protected, including the Metro, the tunnel under the Øresund strait towards Sweden, the land-based anchoring of the large Øresund bridge, Copenhagen Airport, and the low-lying rails leading into Copenhagen central station.

It is noteworthy that the plans are unevenly detailed and mostly remain at the initial policy management stage. They are mostly not yet in empirical implementation, just as they are not yet fully funded. The subprojects furthest towards realization are those associated with rain storms (lakes, streams, reservoirs, sewers). Projects addressing SLR remain the least detailed and the furthest from implementation, although this is recognized as the greater risk already in the 21st Century. The exception is the already ongoing raising of the dikes on the southern part of Amager Island, aimed at protecting against a 10.000 year extreme event with dikes above 5.9 m.

Copenhagen is a very clear case of redesign by resistance rather than adaptation, in spite of the considerable resources and options available. All plans developed during the last decade deprivilege ecological and biophysical domain considerations. They operate with the assumption that an outer peripheral technical engineering solution in the form of hard dike mitigation is the most appropriate and expedient. Primary consideration is here granted to the lesser operational encroachment on the existing city with its sociohistorical milieux and recreational areas. This anthropocentric assumption is accompanied with other major advance mitigation tendencies in the city. The Copenhagen municipality appears to consider it further mitigation to extend urbanization into the ocean via several new large landfill projects for artificial islands (notably the Nordhavn and Lynetteholm projects), although the plans for these are so far underestimating future SLR scenarios.

3.1.6. Jakarta

The capital of Indonesia on the northwest coast of Java, the most populous island on the planet, expands the rise of scale evident in the sequence of the five cases above. Jakarta is a deltaic coastal megacity, located at the mouth of Ciliwung River, with regional status as 664 square kilometers housing a population exceeding 10 million. The wider metropolitan area includes a handful of satellite cities bringing the total population above 35 million already in 2021. This economic, political, and social center of the country is still seeing considerable immigration and rapid, partially unplanned urban growth. Furthermore, Jakarta is infamously known for the complexity of the social, technological, and ecological challenges it currently faces. It is challenged by overpopulation since the influx in the 1960–70s which effectively meant that land use planning and urban infrastructure never caught up. It is exposed to earthquakes, and it suffers from heavy pollution in the city and its environment. Its status as the fastest sinking city in the world (up to 17–25 cm a year) is mainly caused by uncontrolled groundwater extraction from the most vulnerable in the informal Kampung communities without piped water. This subsidence and blue freshwater hydrological development alone is likely to submerge one third of the city by 2050, flooding an area 5 km inland. This is exacerbated by rainfall flooding, especially during the Monsoon. Maladaptive land use planning for the low-lying floodplain with 13 river streams means that runoff from the mountains in the south cannot be sufficiently absorbed by land reservoirs nor be handled by the insufficiently developed sewer and canal infrastructures. Tidal waves from the Jakarta Bay plus the rise in the Java Sea due to climate change further complicate the issue of a resilient hydrological infrastructure. The IPCC midrange prediction of a 1 m SLR by 2100 in effect means that this capital with more than 40% of its area currently below sea level is already in a precarious situation. The more severe RCP 8.5 scenario or above would mean an estimated SLR of 1–2.5 m in 2100, up to 10 m at 2300, obviously submerging the city in its current state of development(Figure 7).



(**A**) (**B**)

Figure 7. Inundation map, Jakarta (**A**,**B**), 2.5 m SLR (red color) [94].

In this very resourceful regional megacity, the design operations are proceeding in an uneven, many-pronged, and fairly complex way, and design management is providing ambiguous, multifaceted feedback.

Consideration of the ecological–biophysical domain is generally not a focal priority in itself when the ecological–technological couplings of the capital are considered. Instead, infrastructural viability is sought along an anthropocentric social axis. For example, a greening of the transport system with electric buses is pursued, along with more green areas in public spaces. An investment is made to secure a supply of potable water from elsewhere. Moreover, the city seeks continuation of the project, ever since the large flooding in 2013, to effectuate large-scale renovation of the city rivers, land reservoirs, and flood canals—along with cleanup of the rubbish and debris clogging the water management system. Updating of regional planning and policy initiatives for Greater Jakarta from 2009 to 2020 involves considerably more in terms of ecologically oriented sustainable design. Recent policy initiatives include strategies for greening and protecting upstream areas, rehabilitating forest and land areas, and organizational control of the border area of the river and its tributaries. They also involve such measures as building three reservoirs in the central Ciliwung watershed, renewed maintenance of the flood canals built by the Dutch more than 100 years ago, and initiating programs to improve lakes and ponds. However, both these and other efforts remain not fully realized, hampered by major problems: a lack of wider systemic knowledge of the natural systems (hydrological in particular), insufficient land acquisition, poor governmental cooperation, and low levels of community participation.

If the ecological couplings are not obviously considered crucial, these design operations do reveal a much higher priority concerning changing the approach to the technological infrastructural domain. Here, design operations include the 2008 master planning and the subsequent implementation of a very large scale dike and land filling solution to SLR in the form of the Giant Sea Wall Jakarta and the Great Garuda artificial islands projects. This expensive, dramatic, and massive coastal development project started implementation of the first 8 km stretch in 2014 and is expected to be fully materialized in 2027. Its aims include revitalization of the coastline, considerable land reclamation in the bay, and the building of a water reservoir. Even while under way, this master plan is being critiqued for its capitalizing focus, its social inequities, its maladaptive failure to address the root of the flooding problem in Jakarta, and its cementing of ecological problems [107–109].

However, perhaps some of the most significant developments in design operations in Jakarta derive from major new management plans that imply substantial changes in social–ecological, social–technological, and ecological–technological interdependencies. In 2019, the national government decided to move the capital to the planned city of Nusantara on Borneo in anticipation of future floods. This involves a move of 2000 km to the northeast, expected to be completed in 2045, at least for government and up to 1.5 million civil servants, although the entire social relocation process is currently unclear. It is an obvious ecological–technological concern what the environmental impact will be when a sprawling city built from scratch comes to cover 2560 square kilometers on Borneo, even if the design plan does include nods in the direction of sustainable development goals [110]. From the point of view of social changes, the plan remains marked by inequalities and is not currently considered sustainable in terms of human capital alone [111]. It is also unclear who will stay in Jakarta and who will be relocated. However, this major signal from regional and governmental urban design management partially resuscitates planned or managed retreat as a transition pathway. It counters the very predominant assumption that this adaptive, transformational response strategy is not for capitals or for central large and mega-size cities.

Jakarta is a fairly clear-cut case of resistant rather than adaptive responses to SLR. It does include apparently adaptive dimensions such as relocation and certain greening projects that change land- and water-use. However, these are clearly accompanied by high willingness to modify the environment, mostly via continuation of many existing types of nonresilient operations.

4. Discussion

The findings in the case studies above generally confirm that resistance responses continue to be hegemonic over and above more decidedly adaptive ones. Reinforcing existing defenses and kinds of mitigation and building sometimes very extensive new ones are clearly the preferred types of response. This tendency cuts across environments that are already heavily urbanized and managed and ones that have so far remained unmanaged. It is safe to conclude that the primarily modern Western urban planning legacy involving presumably efficient technological solutions, or engineering 'fixes', overdetermines responses. It is also clear that this legacy and the assumptions behind it form barriers to adaptation, especially the development of other forms of adaption such as more ecologically oriented projects and dynamics of retreat/relocation.

Despite their numerous obvious differences in their transitional situations and future planning, the six cases are surprisingly similar. Potentials for increased hydrological resilience reside in design approaches that reconsider and work differently with what is currently deprivileged and considered 'merely' peripheral. The cases permit one to realize that peripheral cities and the peripheries of coastal cities are of key adaptive import for design developments, from gray through green to blue infrastructures. Notably, then, the case studies establish the way for a discussion on how to reassess the peripheral. A very condensed formulation of what the findings point towards would be to say that a reprivileging of the peripheral amounts to adopting more nonanthropocentric, more decentralized, more dynamically flexible, and more long-term urban design approaches. These findings are presented in more detailed fashion in the four subsections below.

Overall, the findings lead to advocacy of four critical displacements. A first displacement concerns countering overly anthropocentric conceptions of the city/environment distinction. The second displacement consists in a move away from undue centrism in planetary urbanization, both concerning the Global North/Global South distinction and with respect to the distinction between central cities and peripheral or ultraperipheral ones. A third displacement pertains to the issue of rethinking adaptability via the notion of resilience so as to find alternatives to overly static, structural, and general land-based designs. A fourth and final displacement concerns the temporal dimension and almost follows as a corollary from the third. The Anthropocene comes with a very widespread sense of urgency and emergency associated with catastrophic climate change. Nonetheless, resilient adaptability calls not so much for further optimization of short-term, efficient, innovative scientific and technological design and planning. Rather, it calls for long-term thinking, for experimenting considerably more slowly and piecemeal in specific situations, and for staying more and for longer with the trouble of uncertain futures.

4.1. Countering the Human City

4.1.1. Transitions beyond Social Monism and Anthropocentrism

The results from the case studies confirm a relatively general observation: strong social focus means reaffirming and maintaining anthropocentric notions of the city–environment distinction. Seen in a SETS and CAS lens, much research and management of urban design processes tend still to operate with a conceptual, practical, and materially formative hierarchy that grants first priority to social–technological processes and relations, second priority to the ecological–technological, and third priority to the social–ecological. Quite often, this hierarchy is carried out using something akin to a social monism. This involves a type of reduction in complexity that turns ecological–technological infrastructural issues into a pursuit of innovative technological solutions emerging from key niche initiatives that experiment with transitions. Simultaneously, treatments of social–ecological infrastructures tendentially bracket ecological systems. Often, the 'environment' is approached as a social construction through and through. Hence, 'resilience' tends to mean social resilience, 'justice' means social justice, and 'infrastructure' tends to mean societal infrastructure. This hierarchy is mainly coded by a strong anthropocentrism that is very understandable but also tends to remain too much of a blind spot. Design management and design practice implicitly retain a notion of infrastructures as the implementation and maintenance of quite strong distinctions between an inside privileged human urban society and culture and an outside deprivileged environment. Often this happens in spite of attempts to emphasize interdependent relationality, entanglement, and co-development. In effect, both more theoretical research and planning practice often adhere to a privileging of humanity by and for humans. This reduces to a whisper the concerns of the more-than-human, the ecological and environmental, or what used in the modern Western cultures of the Global North to be called 'nature'.

The case studies indicate that the most difficult problems for hydrological resilience for the complex adaptive systems at stake derive from this kind of anthropocentric approach to the metabolism across the city–environment membrane. The vast majority of recent research in the relevant fields also points to the need to decenter the human. This typically means shifting more towards seeing the city as a niche embedded in a co-developmental fashion with its more general and complex biophysical environment. This likely also leads to the recognition that, more generally speaking, the socially designed human city is the asymmetrically less important and more hungry, dependent, or parasitic system [112,113]. The same insight should make clear that planetary finitude dictates that resilience potentials reside with design that establish the way for long-term and mutually flexible metabolic exchanges between urban niche and hosting environment.

However, in all six cases, the modern human, city-centric heritage is operational and is being practically maintained. The clear preference for the scientific and technological hard engineering of mitigating barriers, including advance landfill defenses into the ocean, is perhaps the most obvious sign of the survival of the paradigm of an urban fortification waging battle against nature, supposed to be both other and own resource at the same time. This is accompanied by reinstatements of too expropriative, overconsumptive, and wasteful metabolic exchanges across what used to be called the urban culture–natural environment or society–nature distinctions. Apparently, an exception is the consideration across many but not all six cases of planned retreat as adaptive pathway. However, none of the cases bear evidence that this involves a strong, decentering displacement or a qualitative difference in a SETS sense. None of the cases demonstrate a more biocentrically and/or ecocentrically oriented project. No one case displays an alternative, less modernizing, less anthropocentric urban project with another set of ecological–technological and social–technological relations and processes. Rather, if planned retreat is an explicit pathway, this concerns the option of moving essentially the same modern and anthropocentric urban design paradigm elsewhere. Research and the empirical developments in climate change, SLR included, have shown this type of distinction to be a dead end, for cities, life forms, and ecosystems alike. That evidently does not equal the cancellation, or significant weakening, of the anthropocentric path dependency.

4.1.2. Displacing towards Interdependency

These observations are not entirely new but remain relatively unheeded key insights from environmental and ecological research. The observations here come with a faint echo of a deep planetary time and a more audible echo of a capitalist modernization history, which includes the more recent great acceleration but in fact stretches back across agricultural and urban settlements in the Holocene [114–120]. With respect to resilience potentials, designing with rather than against ecological climate change, including the hydrological dimension of sea level rise, remains the more important driving variable. It is still an open question how to perform displacements that will decenter the human and facilitate experiments with different kinds of interdependency. First hints may be found in the rise of 'the Anthropocene' as a term, one that is now not so much well defined as very polysemantic. In spite of considerable earlier climate change denial and the currently predominant preference for "wait and see" or "doing nothing" approaches, the adoption of the term can at least indicate that climate change is widely recognized as anthropogenically forced. Perhaps "Capitalocene" is the better term [121], but the "Anthropocene" can be a partially useful reminder, in the restricted sense that it can lead to critically observant reconsideration of anthropocentrism along with its alternatives.

The six case studies appear to point out that displacements towards interdependencies are perhaps to be found in different relations with ubiquitous wetness. This not only concerns changing the anthropocentric approaches to groundwaters, rivers, and water from above that we know from modern conceptions of the city–countryside rifts. It notably means changing the approach to the peripheral in the sense of the city–ocean metabolic rifts at coastlines. These peripheral rifts are the openings onto the wider context of rising temperatures that rupture earlier Holocene climatic landscapes for the planetary hydrological cycle and lead into sea level rises. This more important resilience feedback from the oceanic and cryospheric to urban environmental niches is most often left deeply embedded. Nonetheless, even if it is somewhat muted, this feedback is a signal that resilience involves a different urban design polylogue with biocentrism and ecocentrism. A more resilient peripheral approach implies more than granting increased import socially to a scientific, technical approach to nature-based and water-sensitive infrastructural designs. It notably implies doing different relational experiments with the livability and material capability of waters.

Here, the notion of 'the city' being designed infrastructurally with respect to its water sensitive management is to be understood as a participant in planetary urbanization and as relationally expanded. The city as an expanded flow and ebb of infrastructural relations forms and unforms emergently as couplings among social–ecological, social–technological, and ecological–technological subsystems. The city in design is a complex, open adaptive set of systems that interact and change interdependently [122–125]. This dynamic interdependence means, among other things, that resilient city–environment water exchanges are unlikely unless biocentric and ecocentric flows and ebbs are considered co-designing agents. One good recent example of what is still a minority approach in urban design and planning, i.e., the approach that grants primacy to interdependency, entanglement, and an interweaving with ecology and attempts an in-depth investigation of this, can be found in K. Hill's work with a number of colleagues [8,126].

This allows for the general observation that managing infrastructural designs for peripheral water exchanges in a sensitive, expanded sense involves drawing on the assumption of a complex processual and relational ontology. This is a design ontology entangling humans and their planetary urbanization with other co-design agents qua other water-dependent lifeforms as well as chemical and material flows of wetness, each with a voice in design negotiations. It is currently a major, unresolved challenge to change 20th Century laws that are generally grounded on a framing of the environment qua 'nature' as a resource to be owned, and to adopt a more complex, inclusive approach to (hydrological) agents in governmental and policy terms, and in something like concrete living urban design labs.

4.2. Delimiting City Centrism

4.2.1. Centrisms: Global North and Global South, Central, and Peripheral Cities

A key observation to be made in the case studies concerns breaking the barriers to resilience found in undue urban *centrism*, along at least two main axes. One axis concerns the nonresilient asymmetry placing Global North urbanization as central and Global South urbanization as peripheral. The second axis concerns the asymmetries deriving from national and regional differences between central cities such as capitals (e.g., Jakarta, Copenhagen) and inner peripheral or ultraperipheral cities (to some extent Malé and Tarawa, but certainly Birkholm as ultraperipheral).

The contrast between the Danish cities and the three other cases demonstrates that Global North cities enjoy a privileged center status as the more developed and more resourceful, whereas the other three cases have very uneven options but still must operate with less, often accompanied by difficulties with a heritage concerningeecolonization. It is very obvious that a less developed city in Kiribati is negotiating planned retreat unlike any of Danish cities. This issue of retreat is a very clear demarcation between the two hemispheres. The main point at stake here is fairly obvious but exceedingly difficult to bring into governmental, policy, and design practice. Resilience potentials reside with the combination in which Global North cities curb their long path dependency on modernization, growth, and environmental emissions while different and more sustainable kinds of design are adopted not least in the areas of Africa and Southeast Asia, where the most massive new urbanization is expected to unfold.

One significant observation is that modern Western cultural notions of urban design remain privileged across the six cases. This is so even though it is today slowly being recognized in research, but not yet so much in urban design practice that this model does not work well in numerous Global South settings. The 'god trick' of this model, its scientific and technical universalism, and its 'one model fits all' assumption are increasingly being problematized.

The differences along this North/South hemispheres axis are not uniform or unambiguous in the case studies, however. For example, the only strongly adaptive experiment with a more floating city infrastructure could be considered more advanced, if considered from biocentric and ecocentric angles as the more resilient development. Alternatively, however, a more anthropocentric perspective might deem it less advanced and privileged, because it is not land-based and remains more uncertain in a number of ways. Interestingly, this ambivalent project takes place in the developing Maldives, albeit with no little technical and economic influence and support from the Global North. This lends itself to both affirmative and very critical readings. For example, it can be seen as an experiment with the wetter, more flexibly fluid and more ecotone design that cities across the hemisphere might benefit and learn from. Simultaneously, it can be seen as the unjust exclusion and export away from the Global North of the less desirable but necessary other kind of adaptive transition path.

Concerning the second axis, the cases demonstrate that regional and national central urbanization projects are immensely more resourceful socially, culturally, politically, technologically, and not least economically than the peripheral or ultraperipheral cities. Center cities such as Copenhagen and Jakarta are much larger, and they present the more complex and advanced design plans. The strongest marker is the dividing line between the actual or presumed right to stay, to expand, and to complicate infrastructurally via larger projects in hard mitigation (Jakarta, Copenhagen) and, on the other side, the need to adapt by seriously considering retreat and relocation (Tarawa, Malé). This is a familiar pattern for the tensions between center and periphery, which replicates itself across national, regional, and more global scales. Looked at in terms of infrastructural potentials to respond to SLR, extensive and advanced technical solutions are appropriated for central cities. These solutions are to some extent available to peripheral cities, especially if located as well-connected hubs near central cities, as in the Dragør case. Ultraperipheral cities seldom have access to such solutions and are the ones most often engaging actively with planned retreat and migration as an adaptive planning option. Looked at through a number of Global South lenses, this is often primarily a question of being denied or not being denied the developmental passage through the wealthy, overconsumptive modern coastal city.

4.2.2. Decentralizations

The major blind spot lurking in centrisms and the center–periphery lock-in basically concerns the capability to see or not to see decentralized networked and heterogeneously distributed urban systems as the more resilient transition pathway. Insofar as this is still so, it seems that contemporary urban design still could find considerable potential in learning from insights in sister disciplines. For example, a great number of ecological and biological research projects could help point out that resilience is increased via decentralized distribution, redundancy, and variation. Just two examples from the technical disciplines could begin to do something similar. Even if the background in the 1945 atomic bombing of Nagasaki is not greatly reassuring, there are good reasons why the development of the Internet as a dynamic and decentralized network of networks has great survival potential, just as there are good reasons for its very decentralized and redundant communication protocol being so secure. Likewise, it is not a mere accident that the open source coding and decentralized development and testing approach behind the Linux operating system led to one of the most resilient such systems.

Working alongside such dynamical decentralizations is not, however, what characterizes the urban cases in this study. For all six cases, it is worth observing that none of them consider hydrological design operations and management scenarios that involve moving towards infrastructures for the more vertical, provincial scale city intensively networked with its region, which is today known to be the more sustainable. If they do consider partial deconstructions of anthropocentrism in their ecological–technical domain, in the form of more or less self-regenerating nature-based solutions, these are typically decided against. Also, none of the six cases engage more fully with the potentials for coastal cities to design their infrastructural membrane with waters in a more dynamic and flexible way, witness the general rejection of everything connected with planned retreat and relocation if at all possible. Here, thinking the coastal city as dynamically connected with the water in a co-evolutionary condition, including thinking of human social culture as already connected hydrologically by being roughly 75–80% water in a fairly basic bodily sense, could make a difference that makes a difference [127].

It could begin to make visible that the modern urban infrastructural lock-in with the notion of designing for the owned, stable terrestrial territory of the polis fortifying against the waters is the less viable systemic pathway. Being more just to the movement of the lives and ecologies of waters might also be the more resilient movement pattern for the city. Both research and practice hover here today in an undecided way. Designing and living with the territorial flow between the dry and the wet, between advance and retreat, is both known and pursued but perhaps marginally, as in parts of the development in the Netherlands. It is mostly not practiced, though, even when it becomes considered as part of the design proposals, as in the Dragør case but also as in the case of the quite recent landscape architectural design competitions in the vulnerable fjord cities of Vejle and Kolding, Denmark. In effect, however, the dynamism of both biocentric and ecocentric insights remain largely inaccessible in the six cases presented here, even though the greater potential for resilience and justice reside in precisely this wetter periphery. The greater adaptive infrastructural planning potentials are to be found in the designs of the dynamically liquid city as what makes up a shared condition and challenge. The more resilient coastal cities could well be said to be the ones capable of adapting via advance and retreat of city as well as the sea. The critical potential resides with the city that lives with a wetter relational ontology of the sea [128,129], with a different design outlining less dammed streams [130–135] and with the flow of rains and snows.

4.2.3. Decentralized Bottom-Up Movements from Peripheries

The six cases are obviously differently situated in coastal ecologies, different in their climatic and topographical setting, different in their urban historical developments and geopolitical capabilities. However, they are alike in other important ways, which are not always recognized. At least implicitly they acknowledge the need to work with a variety of locally specific, context-aware design operations, because climate changes and hydrologies differ markedly from place to place. They are also alike in meeting centric barriers to resilience. Some of these arise from cities locking into national and global territorial politics and legislation concerning how to draw border lines. Both these similarities hint at peripheralizations and delimiting events as the places and times for other pathways towards increased resilience.

A differential constellation of locally water-sensitive urban designs such as these six might begin to move towards increased resilience. For this to become more likely, they need to scale up but without losing situated water-sensitivity. The need to engage in multiple feedback and feedforward loops coupling structurally and processually with regional design and planning. This is to some extent emergent in some cities and some parts of research [136–145], but it remains a relatively underdeveloped track, compared with the centrist push and pull of nation states as well as key global cities. To make matters more complex, such sets of transversal bottom-up urban design couplings across regions remain blocked potentials due to maladaptive ways of handling moving lines on a map. The heritage from modern empires, colonization, and sovereign nation state building followed by globalization has led to legislated geopolitical borderlines that are mostly terrestrial and static. Resilient water-sensitive cities in a SETS and CAS sense would, but cannot very easily, draw continuously varying borderlines which move in response to climatic and hydrological regime changes in geophysical and ecological landscapes. This is still for the most part an intractable design problem. It remains a clear design management signal, though, that more dynamic and climatic notions of urban 'territories', 'regions', and 'borders' are being called upon in the Anthropocene.

4.3. Resilience as Peripheral

Observing the results from the case studies from a fairly abstract theoretical and methodological perspective may invoke a third critical displacement towards designing in more peripherally sensitive ways. The inclusion of transversal peripheral relations in the urban niche via more biocentric and ecocentric approaches is very likely to be the pathway to more resilient infrastructural design processes. Here, both anthropocentric utilitarian and more biocentric and ecocentric environmental science approaches can be adopted because they can yield the same kind of insight. The utilitarian argument would be that humanity can only live on and thrive in the longer term by recognizing and acting upon an integrated co-existence of humans with the natural world. Both earlier and current research efforts in a resilience context testify to a similar insight. One might do well to reconsider resilience as a peripheral concern. A first move could be to shift focus partially from the broad and ideal United Nations and IPCC goals for sustainability science towards theoretical and concretely practiced urban design management of resilience [57,60,62,65,66,68,146–150]. An approach to resilience might well draw on recent efforts in interlinked social, ecological, and technological systems thinking (SETS) that problematize undue anthropocentrism and instead emphasize both a more complex, expanded systemic approach and engages with biocentric and ecocentric developments as being of more primary concern [67,123,125]. This would be a move generally moving on the same path as other parts of research emphasizing more ecosystematic involvement [151]. As the next two subsections demonstrate, this can be done via slightly earlier and via more recent work on resilience.

4.3.1. Resilience: Persistence through Flexibility

C. S. Holling's now classic work on ecological systems [66] could be revisited to helpfully point out that, currently and in most low-lying coastal landscapes, infrastructural design operations and management are likely to do better by not adhering to a strictly human stability notion of resilience with one anthropocentric domain of attraction. Such a stability approach would presume that a human city exists under climatic and hydrological conditions near equilibrium. It presumes that the city is expected to return from disturbances to homeostasis along the most efficient path that can be calculated and secured by human technical means. This is typically thought as the most effective infrastructures needed for mitigation. Instead, Holling's work would hint that a displacement should take place towards design strategies that engage with the probability of extinction so as to have the flexibility to persist through change—rather than looking towards robustness and a return to stability. A resilient hydrological design would then orient itself towards what the city, viewed as an open and complex adaptive system of systems, can do in terms of absorbing and living on with more or less radical changes in its wet/dry peripheries—and still persist. This implies an acceptance of undertaking difficult and uncomfortably uncertain analytical and practical work with nonlinear systems that may frequently change limits at some distance from equilibrium. It also implies a change in the notion of transitions. Transitions shift away from a focus on the robustness and stability of the limit to the inside and outside of the city. Rather, they open onto instability, change, and more or less radical evolution of infrastructural dimensions and their boundaries. Transitions can here operate with several basins of attraction and more than one equilibrium. They need not place primacy on human sociality attractors and equilibrium.

Holling's text can serve as a design management reminder that the major infrastructural design strategy in coastal cities subject to extreme climatic conditions (sea level rise, rising temperatures, and droughts) concerns opening pathways for continued existence by maintaining flexibility above all else. Pursuit of this begins by affirming the instability of territory, the fluctuation of population, and the heterogeneity of environment. These are three very difficult proposals for management of urban designs.

To operate with one stable and well-structured urban territory is, along with appropriation of land and ownership, a very habitual modern assumption upon which design, planning, and infrastructural construction is based. Opening this up to instability and more than one domain of attraction can obviously increase resilience. For example, it can do so because increased variability would permit movement of the urban system from one territorial domain to another. This is not new, but it touches upon a dynamic mode of urban adaptation that modern or modernizing humans tend to consider as the very last resort or a (natural) disaster. Land use regulation is slightly more acceptable. Thus, currently some cities do manage to prohibit hazardous new construction in obviously vulnerable low-lying coastal areas. However, the continued favoring in many places of advancing via land reclamation and landfilling seems to work against this at the same time, in developed countries especially.

Reading the IPCC reports in some detail reveals that planned or managed retreat (migration, displacement, relocation) is not a new approach, at the theoretical and methodological levels [101] (pp. 385–411), [152] (pp. 2174–2175). However, the scarcity of research done on planned retreat [153–161] and the formidable de facto challenges that this adaptive approach presents are very clear feedback signals that this remains an important blind spot where critical resilience potentials reside. It is tremendously difficult, but it is obvious that under extreme climatic conditions and fluctuations some earlier, more mobile modes of human societal existence as well as other species' more flexible modes of territorial existence display more resilience than late modern urban designs. Urban territorial resilience seems currently to call for more in terms of thinking human urban existence with water in its variable flow [162–164]. Resilience calls for more of a wet relational ontology for urban territorializations [128]. It calls for more in terms of thinking of urban ecotechnological infrastructures as complex membranes with capacity for dynamic fluctuation between retreat and advance or 'going with the flow'.

Heterogeneity of environment displays similar characteristics as a tendential blind spot while already being known as harboring resilience potentials. Opening urban infrastructures to spatial patchiness and environmental diversity rather than urban monoculture is known but still relatively less practiced, although increasingly being experimented with during the last two decades of the greening of cities across the world [165–170]. This movement is less developed and slower with respect to shifts from the grayer to the more blue-green city [11], although nature-based solutions are gaining enough import to begin to change this [171], along with attempts to present models for the fluid city. Concerning the latter, the issue is not so much the shift towards understanding and designing the city as fluid in the sense of adopting a processual view, although that is important. The issue is rather one of heeding the call for a design management that models more mobile and flexible material infrastructures and architectures for existing with wetness and watery flows and ebbs. Again, this is a development simultaneously in its infancy and very old. A considerable number of precursors exist in local cultural and indigenous solutions, but especially the ultraperipheral island cities currently threatened by sea level rise lead into new models, accompanied by analogous experiments in cities in developed countries. Good examples of the latter would be the UN prototype floating city leading to projects in the Maldives but also in South Korea and Saudi Arabia. Other examples exist in the larger-scale infrastructural extension of floating homes solutions to floating urban districts or commons attached to existing land-based cities—as in Amsterdam. This is a development reminiscent of primordial human settlements linked closely with water bodies, such as the floating

Uros islands in Lake Titicaca in Peru, floating villages in Cambodia, Kampong Ayer in Brunei, or Makoko in Lagos.

Fluctuations in population are also well known, especially along coastlines (e.g., seasonal variations summer–winter involving tourism) but often seen as relatively uninteresting or as problematic rather than being valued as resilience potential. Strategic major shifts between staying, leaving, and possibly returning across shorter as well as longer time spans are very much an exception in urban design management strategies. This is all the more so in terms of expanding the notion of urban infrastructure to cater to fluctuations of a heterogeneity of more-than-human lifeforms, sometimes living and moving along with humans, sometimes with just humans leaving and returning. It is interesting that this is much better known in biocentric and ecosystemic research efforts that display much less resistance to working more naturalistically with humans as yet another animal species. The peripheral status in urban design and planning of such an approach to fluctuating heterogeneous populations is evident insofar as it is considered exotically interesting—and because it is shown best in the genre of science fiction. Kim Stanely Robinson's climate fiction treatment of cities changing more resiliently in company with fluctuating animal populations and habitats in The Ministry for the Future is a key example [172].

Both fluctuation of population and heterogeneity of environment contain significant potentials for increased urban resilience. They also both signal a very different approach to management of urban 'resources'. Emphasis is put upon the uncertainty of keeping options open instead of seeking efficient and stable infrastructural closure. Here, infrastructural developments prioritize dynamic and shifting openings onto heterogeneity rather than homogeneity.

4.3.2. Adaptability through Coupled Social–Ecological Systems

The work undertaken 40–50 years after Holling by C. Folke and others, much closer to contemporaneity and climate change in the Anthropocene, would deepen and complicate these kinds of insights [65]. Folke's work repeats Holling's challenge to the dominant stable equilibrium view. It emphasizes the ways in which a resilience approach would rather try to embrace nonlinear dynamics, thresholds, uncertainty, and surprise. His work points towards a decidedly adaptive design management approach, whose responses to social and ecosystem changes include periods of gradual change interplaying with periods of rapid change. It would also include dynamics interacting across various temporal and spatial scales. The emphasis in infrastructural urban design would then be on taking up the challenge of developing adaptive governance systems that couple with environmental systems in ways that increase the likelihood of developments for the longer timespan.

A notable departure here concerns not only the attempt to shift from stability to adaptation notions of resilience. It is also an attempt to change the view of adaptability away from a predominantly negative and shock-oriented notion towards a more optimistic one. This is an approach that would rather consider pertubation and disturbance as potential and opportunity. Folke's work begins to emphasize the ways in which disturbance can touch upon the aspect of resilience that has to do with capacity for renewal, re-organization, and development. Disturbance of an already quite resilient social-ecological system may generate opportunities for doing new things, for innovation and development. Alternatively, in vulnerable or less resilient systems, even small disturbances may lead to drastic developments. This view of resilience as both sustaining and developing in cross-scale interactions involving complex adaptive systems, is one that adds considerable nuance and complexity to the nonlinear times, scales, and speeds of exchanges in the adaptive cycles conceptualized earlier by Holling.

However, Folke's work, also drawing on Gunderson and Holling [173], begins to emphasize the social human system operations rather than the ecological. This means gradually pursuing a policy concept that favors (social human) self-organization, learning, capacity for transformation, and innovation. Folke's work shows great awareness of the interdependency of social and ecological systems as complexly adaptive. It also notes that the great acceleration and current human activities point towards a critical and undesirable transition past a Holocene domain [60]. However, Folke's work could still be said to run an undue risk of asymmetrically favoring the social human transformative guiding of change. This is much in keeping with considerable other portions of transition theory that emphasize innovation. It is simultaneously something that very easily falls into a lock-in with a liberal capitalist political economy, the modern growth and development paradigm, and the technologically inventive drive that remain behind both city-centric design and the more general anthropocentric forcing of climate change. Insofar as this is true, the use of Folke's approach would not significantly strengthen a bio- or ecocentering of urban design management. Nor would it establish the way for significant 'innovation' qua urban degrowth, the less distanced and hungry city, or less rapid, less expansive, and less short-term urban change.

4.4. Designing with Discrepant Timescales

Folke's reiteration of the point from Holling concerning adapting to the longer timespan is itself noteworthy and to some extent represents a major blind spot in contemporary urban design management, including hydrologically oriented work on coastal infrastructure. On the one hand, it is well known that climate change invokes deep historical time, witness the operative planetary historical scales in the geological disciplinary debate concerning the Anthropocene. This is echoed on a smaller scale in the use of historical horizons for IPCC's RCP scenarios, which typically include backward and forward perspectives across world historical centuries. This temporalizing problematic is also echoed in relatively recent work done across the disciplines. A good example would be the historical and postcolonial work undertaken by Dipesh Chakrabarty, in dialogue with Bruno Latour, which problematizes European modern historical consciousness in particular and human historicization in general [114].

The point to be expanded in Folke's text concerning coupled social–ecological systems is that temporalizing shortcomings begin to appear, in the case studies as well as in solid parts of existing research. They all indicate one should try to listen more to a feedback signal that resilient design management implies opening onto flexible, persistent relations with an Anthropocene time, which is one of planetary movement and change. Design management can then not only operate with a human world history, typically drawing on time scales of centuries, nor only with the very much longer biological evolutionary timescales in hundreds of thousands to millions of years hinted at in the preferred use of the terms 'adaptive' and 'adaptability.' It would rather also have to engage with the difference it makes to design with the tens of millions of years in geological epochs in mind, i.e., the designers would be responding to the question of how to design with the flow of time inherent at a planetary scale.

In one sense this is well known, but in another sense it remains a blind spot, especially in the practice of urban design, governance, and policy, and in the operational everyday consciousness of human urban citizens. This strong decentering of the time of the Anthropos is indeed a very difficult signal to heed, in its moves across biological time to material traces of planetary and even cosmological time. It can almost seem an absurdity to imagine a local urban living lab in the 21st Century that has planetary time participating as an agent with legal personhood. In fact, this can appear even more absurd than a spatializing equivalent: an urban living lab in which the hydrological cycle—with its flows of ubiquitous wetness and drought across the heterogeneous spaces of the planetary Earth system—partakes with similar rights. The impression of absurdity probably originates in the recognition of strong discrepancies. For example, this concerns the discrepancies between planetary time and the hegemonic human historical short-termism, especially in the late capitalist modernizing Global North in which financial markets operate with millisecond sensitivity and governance and policy makers operate at best with three-to-five year election sensitivity.

Nonetheless, opening complex adaptive system niches to cuts across systemic timescales matter, and 'resilient design management' is too much of a green/bluewashing term if it does not attempt to consider an opening of the niches of CAS to the hydrological flows of the Earth system in planetary time. There is a gradual increase in awareness of this timescales issue in urban design and management, but it mostly remains at the periphery of urgency discourses and then only rarely opens up to consider more than path-dependent changes over decades to a century. If resilience is at stake, short-termism cannot simply be considered an anthropological constant or an essential human condition even if it is a widespread and recurrent human tendency. The issue then becomes one of countering more or less innate limits to the spatial and temporal ranges across which human designers can come to care about their plans and their consequences. This article tries to advocate working with the expanded ecological range and the longer temporal range, but also with something less demanding than the cosmological. Very many urban design contexts and their conditions conspire against this wider and long-term approach. However, the wager here is that a limited number or just enough thoughtful and diligent citizens and designers are needed to break with such conditions to permit cities not to go under in the near or not so distant future.

Perhaps one of the more resilient transitional pathways to the limit of this historical or temporal regime can be found in a shift towards concerns with tempo. One can embrace a different consideration of the speed of design. This might be a different preventive landscape. It might make a difference that makes a resilient difference to slow the spatial flow and the temporal event of design. That would mean engaging as environmentally poor urban humans, at the periphery of short-termism and emergency rushing of local space, with design movements that change environmental and social things with the slower violence and the slower emission and dissipation [174,175]. Simultaneously, a postfactum, regenerative slow design management strategy can be to grant the time and the local-to-regional spatial relations that enable identification of social–ecological hotspots. Such strategies can be coupled with inclusive social participation and rehabilitation of ecological capability through nature-based solutions, urban degrowth and retreat, and protected ecological regeneration.

5. Conclusions: Future Ecotone Environments

The case studies in this article point to locally specific potentials for a more ecologically oriented resilience. However, the case studies also demonstrate a surprising series of shared potentials, the reprioritizing of biocentrism and ecocentrism first among these. In addition, even if it is a difficult change, one unevenly on the way, it is also an obvious transitional pathway to seek a new mode of decentralized bottom-up regional design and planning. This is to emerge from the infrastructural opening of coastal urban niches at their peripheries to their wider wet environment, primarily guided by local, regional, and planetary climatic and hydrological landscape dynamics rather than the politics, economy and jurisprudence of city- and nation-centrism. There is an obvious need to bring additional critical focus to any continued granting of center status to a developed Global North urbanization as distinct from a massively developing but less central and less resourceful Global South. This is also the case with respect to the difference between currently privileged central cities and deprivileged peripheral ones. Nonetheless, it is a key observation that the late modern social–technological infrastructural blindness to (or deliberate deprivileging of) the urban niche as something ecologically and biotically embedded in effect means that otherwise very different urban situations have their resilience potentials on broadly similar adaptive pathways.

This means one should remark upon and emphasize that the immanently peripheral is the key locus for critical resilience potentials. Put in more systems theoretical terms: if resilience is what is at stake, observations of current observations of design operations and water management should return to the peripheral qua what has been bracketed or has become too much of a blind spot in late modern urbanization. The city exists in a primary sense as a set of material hydrological infrastructural processes in an environment of wetness and drought. The city is forming and unforming in and as a biotic niche, one that is mostly designed to be for our quite watery human species although others live alongside, usually with some difficulty? This is all too obvious when the entry into the Anthropocene pushes critical reexaminations of the modern development of major dams and changes in rivers and streams along with irrigation systems feeding industrialized agricultural food production. It is equally obvious when stable terrestrial urban sewers and the continued networked pumping, piping, and distribution of potable water across urbanized landscapes begin to foreground nonsustainable floods and inundation along with blue water scarcity. It is perhaps less obvious that this implies an anthropologically biased and somewhat narrow focus on gray infrastructures that relate to water and wetness for humans from below and above, blue freshwater from the ground, and dew, fog, rain, and snow from above. The observation of *coastal* urbanization will perhaps more easily permit the different insight that the more primary, large-scale, and long-term infrastructural issue concerns material, ecological and biotic co-design and co-existence with not only the ocean but also the entire oceanic and cryospheric cycle of the Earth system.

The return via infrastructures engaging with SLR to this kind of planetary wetness may lead design management to a different engagement with urban membranes that evince a resilient variation in inflows and outflows of wetness with specific ranges of temperature, volume, and salinity. The transversal move of this observation to the larger scale and longer term points out where an interesting further investigation of the shared design management potentials in the cases in this article could take place. The most demanding and interesting places to investigate for future urban environments are the processes where the ecological hydrological cycles must be met in the most peripherally expanded and complex ways, spatially, temporally, and materially ecologically speaking. The recent Chinese sponge city initiatives might be a first hint concerning redesigning infrastructures capable of engaging with both water scarcity and superfluidity. However, infrastructures coupling with river deltas that meet the sea are perhaps the better focus when inquiring into resilient adaptive pathways for the crossing of the wet and dry, the terrestric and the watery city. This is where the more ecotone environmental dynamics for urban niches can be found. Deltaic urbanizations are very likely to include the more demanding attempts at infrastructures evincing an adaptive territorial co-existence, simultaneously land-based and water-based. Designs here will have to invent destabilizing and restabilizing variations in anchoring and flowing with the waters, and land-based exchanges between retreat and advance, degrowth and regrowth.

This kind of idealized ecotone type or model of the resiliently adaptive city development is clearly mostly a practically unresolved issue. It is a kind of infrastructuring process that is for the most part yet to emerge in a varied set of practical implementations and then undergo further changes. However, concrete cases that grant a first set of approximations do exist in specific kinds of ambiguously interwoven places. These are ecotone in-betweens of delta land that is also an extension of the sea, as well as wetnesses that are also reclaimable as land. Such places would permit more in terms of designing by 'thinking with water', drawing in part on recent research in urban planning, nature-based solutions, and blue humanities cultural theory to begin developing the idea of the infrastructurally and peripherally wet and ecotone city as the more resilient transitional pathway [13,50,128,130,133,162,163,176–179].

This means using more of a dynamic relational notion of ecotone and liquid infrastructural developments [11,26,29,36,123,180–199]. The use here of 'the ecotone' does not only echo Alfred Russell Wallace's 19th Century observation of abrupt boundaries between biomes [200] but draws in an expanded sense on the tying together of the Greek tonos for tension and the much later notion of ecology. It is meant to point towards a more-than-human developmental change in the city, one that involves water cyclical flows and ebbs across several adjacent or partially overlapping ecosystems. Ecotone city systems thus come to include complex processing of relations and stoppages of waters passing through human and other zoologies, biological systems from plants to plankton, and soil and sea materialities from relative coastal land solidities through wetlands to more unruly oceans. An ecotone city design is a complex local and/or regional transition area that develops adaptively, drawing on characteristics from all of these. It is sometimes relatively stable, sometimes markedly variable. The ecotone city may move through abrupt changes and separations, but more often does so with peripheral edge effects. That is, it moves with gradual and blurred transitions across the limits of two or more ecotones. An ecotone city would exist with transitions between different ecological habitats with different biotic communities and different physicochemical features. In this article, the ecotone notably concerns transitions across terrestrial and aquatic dimensions of coastline environments (coral reefs, marshes, mangrove forests, estuaries, grasslands, mountain areas). The term is also intentionally used with some biocentric bias, hinting at ecotones as likely speciating and biodiversifying areas with cost effective conservation traits, i.e., areas likely to be resilient and longer-term viable for life forms [201].

Perhaps two such ecotone cases can serve as an open and dynamic relational conclusion to this article. They are both attempts at flexible and complex integration of aquatic and earthy territorializations. In these two cases, an interesting distinction can be observed. One can design an ecotone to meet climate change but still remain too stuck with land-based hydraulic modernization. However, one can also try to meet hydrological challenges halfway between a wetter Anthropocene and a dryer industrial and agricultural late modernity. This distinction can be found in quite exemplary form by contrasting infrastructural design developments in the Chao Phraya Delta in southern Thailand and the Mekong Delta in southwestern Vietnam.

In the Chao Phraya Delta, as Atsuro Morita has shown [196], the unstable fluidity of water is currently not met with a sufficiently aquatic infrastructure to be considered resilient in a broad ecological–social sense. In 2011 extensive and socially catastrophic flooding, mainly due to surprisingly heavy rains (a 50-year extreme event), revealed both the nonresilience and the complexity of the historical path-dependencies behind it. This was not least the case for the city of Ayutthaya. The nonresilience was in large part a consequence of 20th Century modern nation state design management in the delta region and beyond, which has been terrestrially oriented, especially after 1950. Modern irrigation and road transportation systems for cars led to the infrastructural transformation of the deltaic landscape via implementation of road, dike, and bridge systems. It also led to land-based urban planning initiatives and adoption of Western cultural style buildings. These developments were dependent on dry land (reclamation) in contrast to the more amphibious approach to infrastructures and buildings in significant parts of Southeast Asia.

This is enough to hint that the central amphibious paradigm for the design of the highly water sensitive city prior to the great acceleration, especially prior to the major effects of modern industrial revolutions in Western culture, was made peripheral. Nonetheless, it continued to co-exist and partially overlap as the already installed base on which infrastructural development always draws [202,203]. Urban infrastructural niches always construct both territorial landscapes and specific kinds of social control in the flow of key materials for sustainability [187]. Here it becomes evident that this marshy delta was sought transformed away from an aquatic sociality in order to fit a more terrestrial modern city sociality and its political economy. What was pushed into the periphery returns with a partial right to central focus in the 21st Century, sending both feedback and feedforward signals to design management. Within the vulnerability of the late modern systems and its industrial city complexes the previously predominant aquatic infrastructure reappears, now more front stage. Natural and dug canals reappear, serving as both transport and irrigation systems and frequently inundating land underneath and around stilted houses. For a short while, repressed ecological–technological peripherality displays its resilience potentials. The late modern national politics of water flow control are interrupted by unruly waters that make no major distinction between flooding industrial complexes owned by multinational companies and flooding river-based farming communities in villages.

The Mekong Delta case displays a similar set of historical infrastructural design management decisions, as shown by De Meulder and Shannon [176]. However, it comes with a considerably more complex and promising contemporary revision of design plans. Three hundred years of Vietnamese and not least French colonization of the delta transformed a mostly inaccessible quagmire of endless mangroves with marginal Chinese trading posts and small-scale dispersed Khmer and Cham settlements. This process turned it into a monocultural network of canals and rivers that enabled an extremely rich agricultural and aquacultural mosaic. This is recognized as the generation of the industrial, profitable modern rice basket of Vietnam. It became a high modernist deltaic space, ordered and standardized not least by modern hydrotechnicians into a densely populated and highly productive territory. As in Thailand, an earlier aquatic or hydraulic culture (desakota), sensitive to a variety of modes of living with water, was marginalized and homogenized. This was accompanied by the marginalization of its notion of a flatly networked interlinkage of urban countryside and rural metropolis, something that operated with a mix of consumptive and productive dispersed landscapes.

Here also, contemporary challenges show up the nonresilience and vulnerabilities of a late modern approach to the nexus of water and urban society. This is less due to a single significant flooding event and has more to do with a multiplicity of interlinked fault lines turning up. The current model of land and water management shows itself accompanied by significant losses in biodiversity, increasing problems with pollution, too extensive forest clearing and destructive erosion, water scarcity due to basin overexploitation and upstream dam constructions in China and Laos, and ecological weakening due to too little recession agriculture. This was then combined with climate change effects such as SLR, saline intrusion, unexpected changes between massive inundation and intensive drought, and rising temperatures. As a consequence, the vulnerability of current water management became problematic enough to lead into the proposal for a Mekong Delta Region Plan (2009). The first version of this initiative was an almost catastrophic and dysfunctional attempt to intensify a conventional modern, abstract, and hierarchical planning for cities, steered centrally and oriented towards a sectorial land use in strong tension with the character of the territory as well as the elements of aquatic and urban–rural mixed urban cultures that were still thriving.

Still ongoing work since 2014 on the revised Mekong Delta Region Plan 2030–2050 displays a very different initiative [204]. Although implementations and their effects of course remain to be seen in this ongoing project, it is notable how earlier and peripheralized infrastructural paradigms return. This plan proceeds with primary guidance from an accentuation of the underlying deltaic geography and hydrological flows. More secondary attention is given to the issue of how to construct an interplay with the social, political, economical, and cultural dynamics of this region. This is a proposal for a new artifactual living with the salt and freshwater parameters, the topography, and the soil qualities, so as to try making these meet the regional agroecological subregions in a quite heterogeneous fashion. This design only places as a tertiary concern the pursuit of three major urban–rural morphologies (coastal, freshwater-alluvial, extended floodplain). Moreover, each of these is conceived in an ecotone manner, i.e., as site-specific systems of wet and dry areas. Today, this is a quite rare response to climate change. It is attuned to the hydrological and terrestrial vulnerability of the territory. Perhaps it is not overly sensitive to more biophilic or biomimetically ecological infrastructural design, in the sense of achieving a biomimicry for sustainability and resilience [205]. However, it is unusually responsive to semiecological dynamics between the landscape and ubiquitous wetness. It is possible to hear a muted environmentalist echo of the 1960s and Carson's Silent Spring here, as if the designers seek a partial regenerative conservation of the not too polluted movements of the natural environment. It is almost as if the designers have heeded important ecological ideas very similar to McHarg's earlier call to 'design with nature', by including a very deep feel for a fitness with the quasi-living landscape and its wetness.

The revised Mekong Delta Region Plan still draws strongly on a modern polytechnic and condensing heritage. It also does include obviously nonresilient modernizing components and flagship projects (e.g., an international airport, a deep seaport, intensified agriculture, new agri-industrial hubs, and some increase in road construction). However, the plan is very unusual in its clear departure from building new expensive infrastructure where inundation will be at play anyway. It is also unusual in its downplaying of homogeneous road construction in favor of very selective highway spines with some small local feeders. It is certainly special in its modern upgrading of the canals of an earlier hydrological civilization. Perhaps it pays a potentially problematic homage to accelerated land creation. Nonetheless, it remains to be seen whether the idea of letting this follow the Mekong Delta's mud plain oscillation—between ground and water, sedimentation and erosion, land and sea—will work as the kind of natural self-renewing ecology the designers and planners have intended.

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