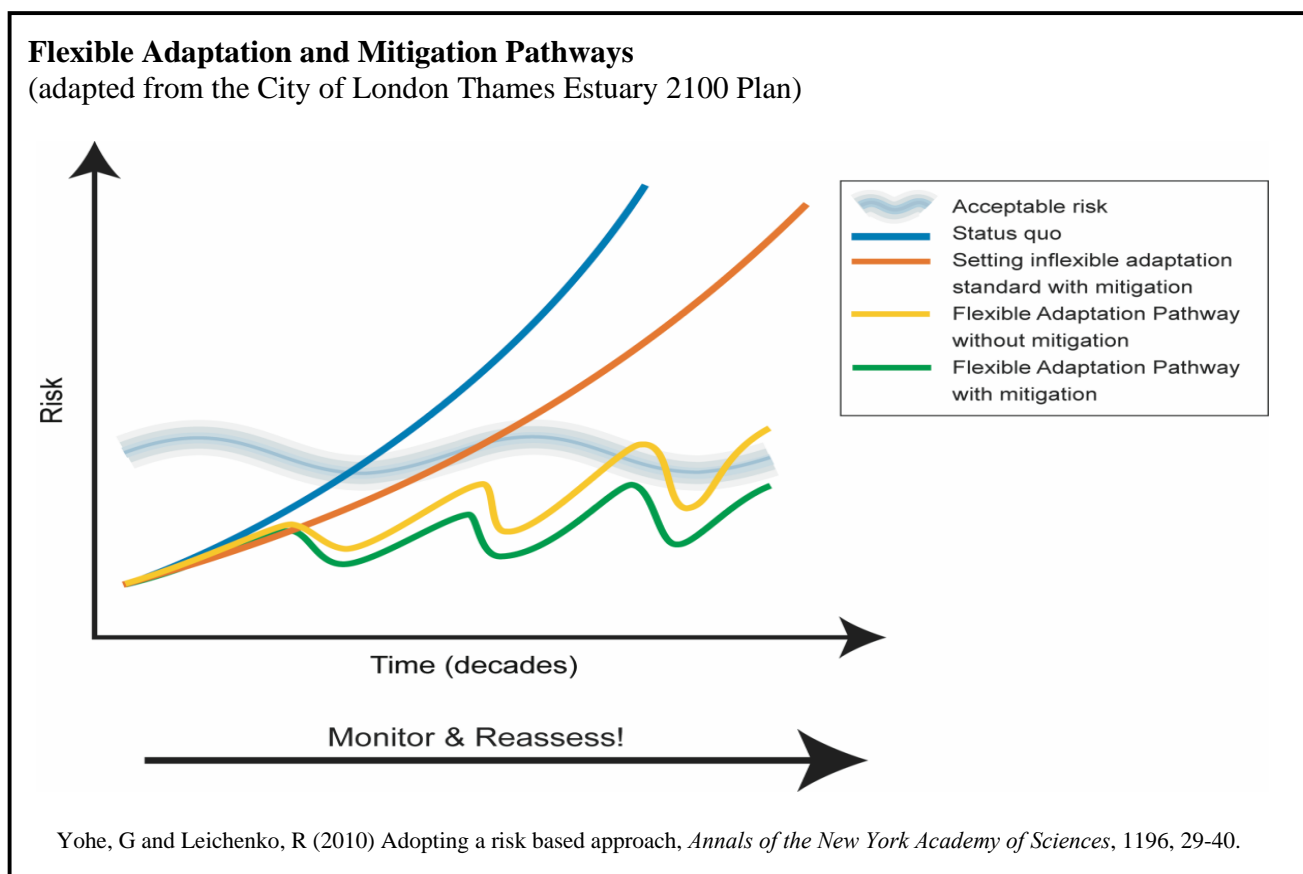

Megacities and the Coast: Transformation for resilience

A preliminary review of knowledge, practice and future research

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Contents

Chapter 1: Introduction	Mark Pelling
Chapter 2: Protecting urban coastal regions of East Asia : what's next?	Poh Poh Wong
Chapter 3: Establishing Sustainable Cities in the Coastal Zone: Taiwan's Challenges and Strategies	Wen-Yan Chiau
Chapter 4: Climate change adaptation and mitigation in East African Coastal cities: needs, barrier and opportunities	Justus Kithiia
Chapter 5: Climate risk and sea-level rise in Rio de Janeiro: an integrated case study	Andrea Ferraz Young
Chapter 6: Reconciliation ecology in coastal megacities: towards a pragmatic framework for sustainability and resilience	Robert A. Francis
Chapter 7: Urban Climate in the Coastal Zone: Resilience to Weather Extremes	CSB Grimmond
Chapter 8: Addressing Coastal Conundrums	T. Schlurmann
Chapter 9: Communicative Resilience in Coastal Megacities	Bruce Evan Goldstein
Chapter 10: Governing climate change in coastal megacities: towards resilience and transformation?	Harriet Bulkeley
Chapter 11: Syndromes assessment and critical approaches in the context of coastal urban resilience David Manuel-Navarrete	David Manuel-Navarrete
Chapter 12: Adaptive Urban Governance: Scale Challenges for Coastal Cities and their Planning Processes	Joern Birkmann

Section One: Introduction

Introduction

The opening figure on the front cover of this report illustrates just one set of possible planning futures for coastal megacities and urban regions facing variation in environmental risk levels. Perhaps of most relevance to this report is the possibility that urban futures are not path dependent. A more flexible approach to adaptation – one that includes experimentation and action on social, institutional and ecological as well as physical infrastructure – offers real scope for risk reduction in a dynamic context. Where this integrates the demands of climate change mitigation risk is lowered still. By noting the decadal pace of change in cities the figure also flags the urgency of acting now, transforming urban development onto a more resilient path will take energy, leadership and time – perhaps the latter is most pressing of all. But significant opportunities exist to re-direct development practice based on and in conversation with science. This is so both in rapidly expanding cities where there is great scope to build resilience into planning and design, and also in older urban centres where new functions in established places as well as retrofitting and smart risk management can generate significant benefits with minimal political and economic risk.

This report is an initial effort by LOICZ to bring together scientists from a range of coastal regions and academic disciplines to map out the state-of-the-art and future research frontiers in science for resilience and transformation in coastal megacities. It draws from a workshop held on 30-31 May, 2011 in King's College London and supported by LOICZ and IGBP. The meeting and this report are background resources for an ongoing, high-level synthesis report managed by LOICZ for IGBP. This is one of several synthesis reviews being prepared under the overall auspices of IGBP, who also supported this workshop. The aim of the report is not to be comprehensive but rather to indicate the range of knowledge, data and expertise that exist, to identify useful directions for the report and initiate the synthesis process.

The report seeks to begin to answer the following questions:

1. What are the properties of urban systems on the coast that makes them especially vulnerable, or resilient to the interlinked pressure of global environmental and economic change?
2. How well placed are existing scientific institutions and epistemological framings of research to identify, understand and offer policy advice on the underlying processes that shape risk and resilience?
3. What might some of the most important areas of future work be?

Addressing these questions requires perspectives that can examine the macro-processes and structures as well as the local dynamics that shape what happens in individual cities. The common influence of such global flows (in finance, ideas, technology, pollution etc) allows lines of comparison and common interest, while context influences strongly local manifestations of risk and resilience. Competing interests conceive of the city differently and place value on different aspects of urban life – from the city as an engine for economic growth, to an organism sustained by critical infrastructure to a place that can support livelihoods and offer space for intellectual, political and cultural experimentation and freedom. The balance in the ways in

which a city is viewed influences those attributes that are most valued and what might be preserved, enhanced or abandoned in processes of transition, transformation and resilience.

Contributing authors to this report offer their own understandings of transition, transformation and resilience – terms that are increasingly contested within academia, just as they become more commonly used in policy. The core, shared understanding here is that resilience indicates a degree of security from hazard. Transition and transformation suggest pathways of change are needed to achieve a desired state of resilience – or indeed a dynamic capacity of resilience that can adapt as the landscape of risks and opportunities facing a city, its ecology and residents changes over time. The preferred focus of resilience is that which combines a concern for adaptation and mitigation goals, though some authors apply the term with a more limited interest in adaptation alone.

The speed with which work on coastal megacities and urban regions has climbed the policy and research agenda reflects a concern for the scale of risk and potential for concatenated and systemic impacts of failure that could spread from cities to infect the global economy and political environment. This is in addition to the large (but not majority) urban population that resides in such cities. There are perhaps seven features of large coastal cities that generates specific character to their vulnerability:

1. The concentration, through processes of historical accumulation, of crucial physical assets, productive industries, energy installations and exposed populations.
2. The over-representation of migrant population and resultant cultural and socio-economic diversity.
3. The extensive reach and dependency of large cities on coastal and interior networks of critical infrastructure (energy, water, food, water, finance) that spread vulnerability beyond the urban core.
4. The layering of coastal hazards – subsidence, salinisation, liquefaction, sea-level rise, on generic environmental burdens especially of the poor including inadequate sanitation and access to drinking water and urban air pollution.
5. Capacity to trigger economic contagion at national, regional and global scales through the strategic importance of coastal cities as centres of global trade and finance.
6. Hotspots for new ecological assemblages, especially in the aquatic environment as a result of degradation, abandonment and alien invasion.
7. A major source of intervention (through pollution, building, dredging or extractive resource use) in biophysical systems, which in turn feedback on urban hazard profiles.

But coastal cities also offer opportunities for resolving hazard. Competition over land and its high value together with social diversity can stimulate focused innovation, investment and flexibility, land-sea interactions can provide hazard mitigation through cooling and the discharging of pollutants.

Overall it is perhaps the additional degree of interdependency and dynamism between natural and human systems that gives coastal megacities and urban regions their character. These cities have specific hazard concerns (tsunami, sea-level rise, coastal flooding, etc), but are also places

where historical legacies of development result in the amplification of risks felt also in inland cities (heat-wave, landslide, pollution).

Following this introductory section, the report is structured into x sections. Section two integrated case studies from Rio de Janeiro, Dar es Salaam, New York and Taiwan illustrate some of the challenges and risk management approaches at hand. Third, contributions focusing on ecology and atmospheric features explore the opportunities for risk management offered by the natural world and indicate the importance of studying the unfolding of ecological, atmospheric and other natural/physical processes in and acting on cities. Fourth a collection of viewpoints offer insights into urban resilience and its management from distinctive theoretical and methodological experiences. Finally in conclusion some core strands that emerge from these contributions and associated discussions are presented.

Section Two: Integrated Case Studies

Chapter 2: Protecting urban coastal regions of East Asia : what's next?

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The Low Elevation Coastal Zone (LECZ) of less than 10 m above sea level accounts for 2% of world's land area but contains 10% (600 million) of world's population and 13% (360 million) of world's urban population (McGranahan et al 2007). A large proportion of this coastal population is in the deltaic areas of developing countries particularly in East Asia which stretches from Pakistan to South Korea, including Southeast Asia.

East Asian urban coastal regions

Of the more than 30 megacities (population more than 5 million) in East Asia many are located in the megadeltas. With a fast urbanization rate, these cities face inadequate infrastructural facilities, e.g. water supply, housing, jobs, etc. Some cities have large sectors of informal settlement.

The East Asian megadeltas are vulnerable to a combination of extreme climatic and non-climatic events causing substantial economic losses and fatalities. The most exposed include the deltas and megadeltas of Huanghe, Changjiang and Zhujiang (China), Song Hong and Mekong (Vietnam), Chao Phraya (Thailand) and Ayeyarwady (Myanmar) (Cruz et al 2007).

The monsoon part of East Asia is the region of typhoons and cyclones and its coasts receive about 42% of the world's tropical cyclones. The intensity of damage by intense cyclones has increased significantly in India, China, Philippines, Japan, Vietnam and Cambodia (Cruz et al 2007).

The coastal cities in East Asia are also affected by non-climate hazards, such as earthquakes and tsunamis. Many are located in the Pacific Ring of Fire (over 75% of world's volcanoes and source of 90% of world's earthquakes) (Jha and Brecht 2011). Eight out of the 10 most populous cities in the world, including Tokyo/Yokohama, Seoul/ Incheon, Osaka/Kobe/Kyoto, Metro Manila and Jakarta in East Asia, have moderate to high earthquake hazard (Ranghieri et al 2008)

The most recent geohazards affecting coastal East Asia were the December 2004 Indian Ocean tsunami and the March 2011 Japanese earthquake and tsunami with a death toll of about 250,000 and 30,000 people, respectively. The high fatality rate from such geohazards is also aggravated by rapid urban growth. The high human and economic losses are a result of "too many people with too little choice in where they can live" (Jha and Brecht 2011: 3).

Within East Asia, the most impacted countries from climate change would be China, Vietnam and Cambodia (Reid et al 2007). The megadeltas in Vietnam and China are most vulnerable and, in particular, the rural poor in the coastal areas as they have virtually little resources to protect from climate change. Large numbers of the coastal population are in poorly constructed shelters and lack financial resources to cope with the loss of their property (Jha and Brecht 2011).

The projected sea-level rise will affect millions of people living in the low-lying areas of East Asia. By 2100, even with a conservative estimate of 40-cm sea-level rise, the population flooded in the coastal areas would rise from 13 to 94 million. In Southeast Asia alone, nearly 19 million additional people will be flooded annually, specifically from Thailand, Vietnam,

Indonesia and the Philippines (Cruz et al 2007). With a rising sea level, the associated impacts include coastal erosion, salinization, spread of diseases, etc.

Protection – what’s next?

For coastal East Asia, it should be recognized that there is a need to consider disaster risk reduction and climate change in the management of the urban areas. Adaptation of coastal settlements to climate change should include mitigation, migration and modification. The last two strategies are not easy as the options for moving inland and modifying homes for better adaptation to climate change would have been foreclosed, especially for coastal settlements in low-income countries (McGranahan et al 2007). It should also be noted that from the start of adaptation, these urban areas already have a pre-existing adaptation deficit, i.e. an inability to deal with existing vulnerabilities and today’s risks (Jha and Brecht 2011). Several approaches are outlined here in a stepped up conceptual approach to protection/adaptation.

(1) Reducing risk factor. One could start with a general risk factor faced by the coastal urban communities, where Risk (R) = probability of hazard (P) x exposure of people and assets (E) x vulnerability of people or place where it will occur (E). The approach is to reduce one or more the three factors in four sequential actions : (1) Avoid the hazard if possible; (2) Investing in generating and disseminating credible information on hazard risk; (3) Withstand the effects of hazard; (4) Prepare for and recover from its impacts (Jha and Brecht 2011).

(2) Building sustainable, hazard-resilient coastal communities. From the opposite end of risks, one could build a hazard-resilient coastal community. Planning can offer a twin approach : a ‘locational’ approach that restricts development in hazardous areas; and a ‘design’ approach that employs design criteria and building standards to ensure ‘safer’ development (Glavovic 2008).

(3) IPCC trilogy for sea-level rise. For adaptation to sea-level rise, the IPCC has a trilogy of strategies – managed retreat, accommodation and protection. While various hard measures have been the norm, soft measures are now considered. In Europe, the Dutch have gone beyond the standard trilogy with variation for the protection strategy and a new offensive strategy (Vellinga 2009). However, it should be noted that the social and cultural impacts of sea-level rise have not been adequately addressed and are just beginning to be explored (Oliver-Smith 2009). One potential area is the value of traditional environmental knowledge (TEK) and practice in adaptation to sea-level rise.

(4) Incorporating new information. It is often stated that technology is important and need to be transferred to developing countries and incorporated into adaptation to climate change. One effective way is a robust strategy to design technology over time in response to new information. Robust decision making (RDM) can highlight policies that provide effective measures against undesirable future outcomes. An existing example is risk-based land-use planning that includes the role of green-spaces and environmental buffers (Jha and Brecht 2011). The proposal of large-scale mangrove planting for protection of eroding coasts and against future sea-level rise is one such strategy that can benefit with better information in future.

(5) Incorporating ecological elements. The use of ecological elements in adaptation is part of incorporating technology and knowledge in adaptation. This can be seen as a further stage in the evolution of thinking in adaptation to sea level rise with ecosystem based management of coasts as a system and not just a physical environment separated from the human environment.

In the coastal populated areas, there is promising scope in incorporating ecological

elements into shoreline stabilization and coastal engineering but this requires strong collaboration between engineers, managers and ecologists. Although, this approach has yet to generate a 'recipe book' for ecological engineering, progress can be made with more experimental collaboration between engineers and ecologists (Bulleri and Chapman 2010).

Within East Asia, the ecosystem-based adaptation is a long-term cost-effective approach that can be used in conjunction with other disaster management and climate change adaptation measures in order to reduce the vulnerability of coastal populations (UNEP 2010). In Louisiana, USA, where the loss of coastal marshes had accelerated the loss of coastal land and increased the vulnerability of the population, it should be noted that every 2.7 miles of marsh is capable of absorbing one foot of land surge of a hurricane (Oliver-Smith 2009).

(6) A socio-ecological system where adaptation process is implicit. Probably the next likely stage in climate change adaptation is to push adaptation as a process implicit in the response of a socio-ecological system. One should therefore address the problem of coastal urban population not from an environmental perspective of a rising sea level rise or from the human perspective of urban planning and management. One should think towards a convergence of both the natural environment and the human environment to produce a socio-ecological system where the adaptation process is implicit (Oliver-Smith 2009).

A couple of examples of socio-ecological systems for mitigating coastal erosion and sea-level adaptation can be cited: (1) In the deltaic area of Bangladesh, silt is channelled into local depressions ('beels') which create high ground for agriculture (Sengupta 2009). Although not evaluated as a technique against rising sea-level, such measures based on traditional knowledge, should be assessed. (2) Mangrove planting is a traditional activity in tropical East Asia and has been actively encouraged, especially after the December 2004 Indian Ocean tsunami. With proper testing the rapid planting of mangroves using a modular system can develop into a bioengineering recipe against sea-level rise (Wong 2010).

Conclusion

The adaptation of coastal urban areas should be conceptually seen as an implicit response of a socio-ecological system in which various disciplines need to converge to find effective adaptation measures that are effective in the long-term. In the planning, development and management of urban coastal areas in East Asia, issues of urbanization, natural hazards and climate change have to be considered. Local TEK coupled with new technology may be one area worthy of further research.

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Chapter 3: Establishing Sustainable Cities in the Coastal Zone: Taiwan's Challenges and Strategies

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I. Introduction

The coastal zones is an important asset in sustainable development given its numerous functions and benefits. The rich diversity of coastal societies, cultures, and lifestyles clearly reflects the very close but varied relationships that have developed over time. As an essential component of national history, the coast is a public area which must be subject to sustainable use. The coast also provides sustenance, allows financial ventures to thrive, and is home to coastal communities that are dependent on coastal resources for their livelihood, employment, and recreation. The coastal areas are places of increasingly important vibrant and diverse economic activities. Abundant and diverse biological and zoological life forms are commonly found in coastal waters. All the while, tides, currents, winds, and waves are constantly shaping and reshaping the coastline. Briefly put, the coastal zone is both an ecological place and a dynamic place with high energy. Moreover, the coastal zone is a place of governance. Many players serve various roles in coastal affairs, including organizations and individuals from many different sectors, such as fishery, mining, and agriculture, from all levels of government, civic organizations, the private sector, and coastal research communities. All of these factors highlight the necessity of integrated management of coastal zones.

Climate change, meanwhile, is an inevitable and urgent global challenge with long-term implications for the sustainable development of all countries. According to the Intergovernmental Panel on Climate Change (IPCC), a warming climactic system is expected to impact the availability of basic necessities like freshwater, food security, and energy, while efforts to redress climate change, both through adaptation and mitigation, will similarly inform and shape the global development agenda. The links between climate change and sustainable development are strong. While climate change knows no boundaries, many countries, particularly the under-developed countries, will be among those most adversely affected and least able to cope with the anticipated shocks to their social, economic and natural systems. The IPCC projects that by 2080, millions of people will be displaced due to sea-level rise, with densely-populated and low-lying countries, like many small island countries, facing the greatest threat from storm surges and rising seas. Therefore, sustainable development in the context of climate change deserves the top priority on the national agenda. This is particularly true for the sustainability of cities in the coastal zone.

II. The 2011 East Japan Earthquake

The 2011 Tohoku earthquake, officially named the Great East Japan Earthquake, was a magnitude 9.0 undersea megathrust earthquake off the coast of Japan that occurred on 11 March 2011. It was the most powerful known earthquake to have hit Japan, and one of the five most powerful earthquakes in the world since modern record-keeping began in 1900. Triggered by the

earthquake, destructive tsunami waves with heights of up to 38.9 meters (128 ft) struck the coast of northeastern Japan, traveling as far as 10 km (6 mi) inland in some places. In addition to loss of life and destruction of infrastructure, the tsunami caused a number of nuclear accidents, of which by far the most serious was an ongoing level 7 event and a 20-km (12 mi) wide evacuation zone around the Fukushima I Nuclear Power Plant. The overall cost could exceed \$300 billion, making it the most expensive natural disaster on record. The Japanese National Police Agency has confirmed more than 15,000 deaths, 5,000 people were injured, and another 10,000 people missing across 18 prefectures with more than 125,000 buildings damaged or destroyed.¹ The devastating incident demonstrated the power of a natural disaster and the vulnerability of densely populated cities in coastal areas.

III. Vulnerability of Coastal Zone in Taiwan

Located in the west rim of the Pacific Ocean, Taiwan is also on the dangerous “Pacific Ring of Fire” where earthquakes frequently occur. Tsunami is a potential threat after earthquake. In 1867, for instance, tsunami hit the north coast (Keelung) with waves of up to 7.5 meters.² The northeastern and southwestern parts of Taiwan, in which three nuclear power plants are located, are particularly vulnerable because tsunamis have happened before.

Along with climate change, extreme weather events are a major concern and pose uncertainty and threats to Taiwan’s coastal cities. According to recent domestic research, typhoons, floods and draughts will be more frequent than ever before in Taiwan and may cause severe damage in terms of the loss of food, human life, public facilities and private property. For instance, Typhoon Morakot caused tremendous devastation in Taiwan in 2009. The storm brought record-breaking rainfall of 2,900 millimeters (114 inches) in just three days. The first floor of many buildings was submerged in floodwater and many counties isolated. Military units were deployed to help with the rescue and reconstruction efforts. Satellite images revealed that the heavy rains triggered huge mudslides and brought severe flooding throughout southern Taiwan. One mudslide buried the village of Xiaolin, killing an estimated 500 people in an instant. Furthermore, the typhoon also resulted in the incidents of some 15 vessels grounded and oil spilled in the coastal zone.

In September 2010, Typhoon Fanapi caused NT\$3.76 billion of agricultural loss in the south and severely flooded Kaohsiung City, the second largest city and a major harbor in Taiwan. The typhoon also caused some 100 deaths in the coastal areas of Mainland China. Both Morakot and Fanapi revealed the vulnerability of Taiwan’s coastal areas.

IV. Emergency Response and Institutional Challenges

Given the condition of the national response system to Typhoon Morakot, many challenges still confront Taiwan. For instance, the national land use planning is an urgent task on the environmental agenda. There is a necessity to enact an exclusive *National Land Use Planning Act* to meet the emerging needs and properly address the environmental concerns, especially in

¹ 2011 Tōhoku earthquake and tsunami, available online at http://en.wikipedia.org/wiki/2011_T%C5%8Dhoku_earthquake_and_tsunami (2011/5/15).

² Scientific American (in Chinese) (2003), Can tsunami occur in Taiwan? Available online at <http://sa.ylib.com/news/newsshow.asp?FDocNo=635&CL=32>

the context of climate change. It is essential to form an exclusive agency, such as one similar to Federal Emergency Management Agency (FEMA) or Department of Homeland Security in the US, to oversee all the response efforts. The ability to dispatch military troops for emergency rescue and cleanup will be necessary. A platform is also needed to coordinate and integrate the rescue, sanitation, cleanup and reconstruction activities carried out by the numerous enthusiastic NGOs involved. The record-breaking rainfall is a sign that the natural disasters will be more frequent and intense than before due to climate change. The design standards of public works such as bridges, roads and seawalls should be reviewed and enhanced to combat the impacts of uncertain weather conditions. In order to handle hundreds of thousand tons of draft wood and debris in coastal areas, a well-planned collection and cleanup mechanism will also be essential. In other words, the disaster highlighted the importance of having new perspectives on coastal development and relevant institutions in the context of climate change.

In addition to emergency response, a long-term institutional revolution to cope with the challenges of climate change is a must. Many countries, Australia for example, have established an exclusive agency in charge of climate change affairs. In Taiwan, the Environmental Protection Administration (EPA) is in charge of the overall environmental management of this country. Established in August 1987, the Taiwan EPA was charged with the major task of “pollution prevention and control,” which includes environmental impact assessment, air and water pollution control, waste recycling, and management of toxic substances. The Taiwan EPA will be upgraded to become the Ministry of Environment and Natural Resources (MENR) next year, so as to strengthen the protection of natural resources and the ecosystem. In other words, the Taiwan EPA will be integrated with many other agencies, such as the Water Resource Administration, the Central Weather Bureau, the National Parks Service, the Forestry and Wildlife Service, as well as the Geological and Mineral Resources Administration to form the new ministry. With this major transformation, we expect the performance of environmental management as well as climate change response to be much more improved than ever before. And the integration of pollution control and nature conservation will most certainly be strengthened.

To handle coastal issues, Taiwan’s Ministry of the Interior has been drawing up the *Coastal Management Act* since the early 1990s. The objectives of this bill are to: (1) protect, conserve, rehabilitate, and manage the coast including its resources and biological diversity; (2) set up goals, objectives, and guiding principles for national coastal strategies; (3) establish an integrated management and administrative framework for the sustainable development of coastal zones; and (4) encourage the enhancement of knowledge of coastal resources and mitigate the impacts caused by human activities in coastal zones. However, the draft bill has been in limbo in the Legislative Yuan (Congress) with little hope of being passed into law. Many fishermen associations are opposed to the act due to worries about losing their fishing rights if the act is passed. Marine education to raise the environmental awareness of fishermen is essential. All the above institutional changes manifest the challenges Taiwan confronts.

V. Promotion of Low-Carbon Society

Mitigation and adaptation are the two major strategies to respond to climate change. The Taiwan EPA is actively promoting the reduction of greenhouse gases and has already set the national target of reducing CO₂ emissions. For the short-term, CO₂ emission will return to 2005

level by 2020, the mid-term is to return to 2000 level by 2025, and the long-term to return to 50% of 2005 level by 2050.

With the rising concern about the devastating impacts of climate change, the Taiwan EPA is actively promoting the management of carbon footprint. In February 2010, it completed the guidelines for calculating carbon footprint, and within two months Taiwan started carbon labeling and became the 11th country in the world with a carbon labeling system. The Taiwan EPA also launched a low-carbon homeland program recently. The “Low-Carbon City” program envisions the promotion of low-carbon urban districts between 2010 and 2011, followed by allocation of 30 billion NT dollars (US\$946 million) from 2011 to 2014 to create six low-carbon model cities. By 2020, four “low-carbon living spheres” will be created in Taiwan’s northern, central, southern and eastern regions respectively. The Taiwan EPA will select the low-carbon model cities through a competitive procedure and will establish a mechanism for private-sector participation, whereby private enterprises will be invited to sponsor public facilities and invest in the low-carbon city program. In the future, the agency will continuously encourage companies to become carbon neutral by using renewable powers or energy saving to offset their emissions. Eventually, it is believed that these efforts will lead to the reality of a low-carbon society which helps to lessen the impacts of climate change.

This is a challenging task with a high degree of complexity. Energy consumption structures need to be changed, and most importantly, people need to become aware that low-carbon lifestyles are the way to improve the overall quality of life and live in closer harmony with nature. It is important that such efforts will lead not only to greener lifestyles for local residents, but increase employment opportunities, and create an environment conducive to the organic growth and duplication of such communities and also the participation of energy service companies (ESCOs) in the building of low-carbon communities.

VI. Strategies to Strengthen Sustainability and Resilience of Coastal Cities

Despite the devastation caused by the 2011 east Japan earthquake and the resulting tsunami, the events have offered many lessons for other countries such as Taiwan to learn. This is particularly true in the new perspectives of planning and management in the coastal zone. Located by the “Pacific Ring of Fire” and on the route of frequent typhoons, Taiwan must take coastal development very seriously. Well-thought-out anti-disaster planning and mechanisms, therefore, deserve the priority on the agenda of coastal cities. In order to strengthen sustainability and resilience of coastal cities, some strategies are recommended for further discussion as follows.

1. Enacting the *Coastal Management Act* to enhance coastal zone planning and management in Taiwan as well as combating natural disasters such as sea-level rise, storm surges and tsunamis, which should include regulations such as setback in the coastal zone, new building and land-use concepts in the low-lying and/or subsided areas and relocation of major facilities;
2. Integrating river basin and coastal management to coordinate management jurisdiction of related agencies along rivers so as to raise the performance of flood control;

3. Encouraging research and development of renewable energy to lessen the dependency on fossil fuels and nuclear power as well as reducing the risks of those plants located in a coastal zone;
4. Strengthening of food security including the protection of farmlands, the incentives for establishing food cities as well as the environmentally sound development of coastal and marine aquaculture;
5. Coordinating humanity aid during emergency response to devastating natural disasters in the region; and
6. Establishing the “Asian Alliance on Sustainable Cities” to exchange the concepts, information and experiences of sustainable cities in the Asia-Pacific countries for the shared benefits of the region.

VII. Conclusion

Climate change challenges and increasing threats in coastal zones are clear and tangible. It is now the time to rethink the conventional development philosophy and concepts and turn them into a new paradigm of sustainable development. More discussion and sharing of valuable experiences will lead to greater knowledge and inspiration in the establishment of sustainable cities in coastal zones, as well as improved environmental policy formulation in Taiwan and elsewhere.

Chapter 4: Climate change adaptation and mitigation in East African coastal cities: need, barriers and opportunities.

Justus Kithiia

1.0 Introduction

The intensity of future climate change impacts is likely to increase current vulnerabilities and further reduce existing adaptive capacities in major coastal cities of East Africa. The current urbanisation of poverty in the region has caused huge intra-urban social inequalities and presents an enormous challenge for these cities to become economic growth engines in a global network of cities, capable of delivering adequate services and quality of life for their rapidly growing population. Climate change impacts are expected to further compound the destitution of the urban poor in addition to affecting both local and national economies.

Although the actual scale of climate change risk in East African coastal cities is yet to be known owing to lack of local analysis, available evidence suggests that climate change impacts will arise from a number of climate-related causes such as sea level rise, impacts on water resources, extreme weather events, temperature-related morbidity and food security (see Magadza, 2000). Even with the limited data, it is widely understood that the contribution of East African coastal cities to greenhouse gas emissions is minimal, but that does not negate the need for mitigation and adaptation measures.

Focusing on the coastal cities of Dar es Salaam and Mombasa in Tanzania and Kenya respectively, I present a synopsis on the issues surrounding climate change mitigation and adaptation by delineating the need for action and highlighting the underlying barriers and opportunities. I contend that despite the likely impacts of climate change in coastal cities, climate change research is extremely limited but growing. To supplement the existing literature, I have drawn on my own research in the region.

1.2 Climate change burden and need for response strategies

An increasing body of scholarship shows that the greatest burden of the impacts of climate change in major urban areas of East Africa is likely to fall disproportionately on the urban poor, who lack the most basic urban services (Kithiia, 2010). The urbanisation of poverty in Africa has seen between 30 and 70 per cent of the population living in informal settlements (Nkurunziza, 2007, UN-HABIT, 2008). Climate change impacts are bound to undermine the livelihoods of these urban poor communities, especially those who depend on coastal resources and are already on the edge of coping capacity. Furthermore, evidence suggests that regions of high population growth such as East Africa, which has the world's shortest population doubling time, coincide with regions of high urban heat island potential (McCarthy et al., 2010). In East Africa, a bigger proportion of this population is expected to settle in the coastal areas in and around the cities of Mombasa and Dar es Salaam. Therefore, considering that poverty alleviation is the main policy driver in developing countries (UNDP, 2008), then the ability to reduce the impact of climate variability and change in these cities becomes an essential prerequisite for both sustainable development and poverty reduction.

In addition to hosting large populations, the seaport cities of Dar es Salaam and Mombasa serve as major conduits of commerce and administration, facilitating the flow of goods to the interior parts of the East and Central Africa region. Coastal tourism in and around the two cities account for a greater proportion of their countries' gross domestic product (GDP). At 10 per cent of the GDP, tourism was the third largest contributor to Kenya's economy in 2007 while in Tanzania, it grew by 58 per cent between 2005-2008 (KNBS, 2007; Mwangunga, 2009). Global sea level rise is therefore a major concern for these cities. In addition, as the cities continue to expand, they will become major sources of carbon dioxide, thus contributing to greenhouse gas-forced climate change. Such impacts combined with an increase in the frequency and intensity of extreme weather events would have a wide ranging socio-economic consequences.

Recent events, though not necessarily linked to climate change, have exposed the vulnerability of these two cities to the impact of climate change, implying the need for action. Heavy flooding has occurred in the recent past in Mombasa and Dar es Salaam, whilst high noon temperatures and humidity in Mombasa have been said to be approaching intolerable limits (Awour et al., 2008; Kithiia, 2010; Shisanya and Khayesi, 2007). Maziwa Island, located about 8 km south east of the mouth of Pangani River near Dar es Salaam has completely disappeared (Sallema and Mtui, 2008), while the continuing impact of coastal erosion on coastal settlements is causing considerable concern to both municipal and coastal resource management authorities³. The need to address these issues, coupled with the influence of Local Governments for Sustainability (formerly the International Council for Local Environmental Initiatives) (ICLEI) in encouraging municipalities to plan to reduce greenhouse gases, makes climate change adaptation and mitigation some of the most pressing issues facing coastal cities not just in East Africa but the world over (see also Roy, 2009).

1.3 Main barriers impinging on effective response

A further body of scholarship is directed at the question of whether successful policy and other responses to climate change in East Africa can emerge given the techno-institutional, financial and skill challenges facing municipal authorities in the region. The municipal authorities tend to experience chronic budget deficits (UN-HABITAT, 2010) hence, within the existing planning and resource allocation frameworks, they have limited resources to invest in climate change response initiatives, such as those requiring huge investments in protective infrastructure. For example, according to a report from the Vice President's Office, the cost of protecting the 100km coastline of Dar es Salaam by building a sea wall would be US\$270 billion (Vice President's Office, 2008), while associated costs for coastal flooding arising from sea level rise in and around Mombasa are estimated at US\$ 7-58 million per year in 2030 increasing to US\$ 31-313 million per year in 2050 (SEI, 2009). This is beyond what both the local and national economies in these countries can afford. This lack of financial capability is also an impediment to authorities to offer protection to slum dwellers, even though the quality of housing and overall infrastructure is an important determinant of people's vulnerability to flooding, storms and urban heat island (Kithiia, 2010). As for the existing infrastructure, it seems to be experiencing what Putnam describes as premature obsolescence (Putnam, 1983). That is, it was designed between the 1960s and 1970s, constructed in the 1980s with the aim of serving until the 21st century, but

³ Interview with the Kenya's Coast Development Authority engineer (CDA) in 2008.

was already over-congested and a cause of public annoyance by the late 1990s. It will require enormous financial resources for retrofitting to make these adaptable to climate change.

The rudimentary nature of the institutional frameworks has also been highlighted. It is difficult to implement strong climate change policies with weak institutional frameworks as is presently the case. The responsibilities and accountabilities for climate change are straddled between several low level and poorly-resourced institutions (Kithiia, 2010). This may be attributable to the absence of explicit policies linking climate change with urban development as issues of mitigation and adaptation are still at the policy formulation stage and tend to be complicated by lack of data. Furthermore, current planning processes do not provide for municipal governments to enforce internal consistency even though effective responses to climate change calls for an integrated planning process in which the municipal authority should play a leading role (Bulkeley et al. 2009)

Capacity building for climate change has often been cited as a critical priority, mainly because climate change is a complex issue requiring complex understanding of cross-cutting issues as well as the inclusion of different actors in the decision-making processes (Laukkonen, et al., 2009). Knowledge is power and whoever has knowledge has an edge in the climate change regime. However, in the East African region, the community of professionals who research climate change has remained small. The knowledge and skill constraints combined with operational weaknesses, such as the absence of proactive initiatives in identifying and addressing problems, and the lack of analytical capacity to advocate for requisite changes among key decision makers constitute serious impediments to climate change mitigation and adaptation responses in the region.

It has further been suggested that major cities in East Africa, including Mombasa and Dar es Salaam, have been 'locked in' the environmental agenda transitions⁴. Consequently, time and space-related impacts have transformed the timing, speed and sequencing of these transitions, with challenges appearing sooner, growing faster and emerging more simultaneously than those previously experienced by cities in high income countries (Kithiia, 2010; Keiner et al., 2005). Formulating strategies that address these agenda issues, and in particular balancing the brown, grey and green burdens remain a major challenge for both municipal and national authorities. Achieving this balance is critical with respect to climate change, whose implications should not just be seen as 'green issues' but as a matter of the overall socio-economic well-being of urban residents.

1.4 Opportunities and prospects for mitigation and adaptation

Regardless of whether climate change remains a peripheral issue or not, opportunities for building adaptive capacity by still exist. These can be found in undertaking developmental activities such as housing, infrastructure, and other poverty reduction initiatives, as well as

⁴ Environmental transitions include brown, grey and green agenda issues. Brown agenda issues include environmental health and local issues such as water and sanitation, air quality and solid disposal; grey agenda issues are associated with industrial urbanisation e.g. chemical pollution; and green agenda issues are associated with future socio-ecological sustainability. For transition agenda issues refer to Marcotullio et al. (2005) and McGranahan, et al. (2007).

forging partnerships with local residents in the spirit of facilitative collaboration. Integrating climate change into urban development could help planners to rethink the traditional approach of designing infrastructure based on weather patterns and changes in sea level experienced in the past and move towards a new approach of risk-based design for a range of climate conditions projected in the future. Furthermore, local residents continue to exhibit exceptional resilience in adopting survival strategies, transforming every opportunity into positive action. For example, Kithia and Dowling (2010) report on how resident groups in Dar es Salaam and Mombasa have organised themselves to reforest the degraded coastal areas to ensure a healthy sea wall among other socio-ecological benefits while Dodman and others (2009) explain how low income urban residents in Dar es Salaam have adopted a variety of strategies to cope with risks. These local capacities can be harnessed to provide a foundation for effective climate change response.

The implementation of the provisions of the new ambitious blueprints, namely, Vision 2025 and Vision 2030 in Tanzania and Kenya respectively, which are geared towards transforming their economies to offer better quality life to citizens, offer a window of opportunity for the two countries to build resilient and carbon free cities. Aiming at low carbon trajectories is likely to ensure that the envisaged future growth avoids spillover into high emission pathways, thus enabling the economies to benefit from low carbon financing opportunities. As late comers in climate change response, the governing authorities can learn from the mistakes of others and open up a possibility to leapfrog into more sustainable cities avoiding the mistakes experienced by those in developed countries. Innovative strategies such as pro-poor low carbon energy access and carbon capture could have the twin objectives of mitigating climate change as well as poverty alleviation.

1.5 Conclusion

The literature on climate change in East African cities is consistently highlighting the techno-institutional financial and skill constraints, and the need to ensure that future impacts of climate change do not exacerbate existing vulnerabilities. However, not much research has been devoted to exploring innovative and cost effective ways of addressing the climate problem. Successful strategies are likely to be founded on robust urban planning processes that seek to reduce the dichotomy between formal governing institutions and networks of actors that provide local capacities. Furthermore, national urbanisation policy frameworks will have to complement local strategies for the envisaged changes to be quicker and deeper, and this includes identifying various levers by which action can be triggered and sustained. These actions are likely to be enhanced if good science (including the use of new data, methodologies and models), is used to inform policy. While plans to achieve a carbon-free resilient urban fabric under the existing conditions may be farfetched, privileging mitigation and adaptation measures still offers opportunities to address the intermediate goal of reducing vulnerability, both to climate change and other weather related stressors.

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Chapter 5: Climate risk and sea-level rise in Rio de Janeiro: an integrated case study

Andrea Ferraz Young

Introduction

This paper intends to describe the impacts of sea level rise associated with intense rainfall events in the city of Rio de Janeiro. In this case the risk situations are associated with society's susceptibility to environmental changes, seen not only as a result of a certain event, but also as a consequence of a social process related to structural urban issues that are linked to political decisions and measures implemented in the course of history.

Rio de Janeiro metropolitan region is one of the largest and most complex urban agglomerations of the Brazilian Coastal Zone, with an estimated population of 11.812.482 inhabitants. The city of Rio de Janeiro, hub of the metropolitan region, has about 6.093.472 inhabitants (PNAD, 2008).

In general, urban areas in the municipality of Rio de Janeiro have expanded intensively in areas poorly suited for urban use, such as wetlands, steep hillsides, outcrops and rocky shores, and estuarine channels, rivers and forest remnants. The interventions are developed on time, appropriating the environmental units in an isolated manner, ignoring the concept of ecological system.

According to Coelho Netto (2007) "the landscape of Rio de Janeiro of the 21st century depicts the historical process of city growth at a site marked by mountain massifs surrounded by the fluvial-marine plains, sandbanks and coastal lagoons."

"From the mid-twentieth century the city underwent a process of accelerated growth, expanding its formal and informal constructions in the lowlands and on hillsides replacing the ecosystems of the Atlantic Forest. The advance of forest degradation has resulted in increasing instability of the hillsides. The increase of sediment supply during and after heavy rainfall has been responsible for the increased frequency and magnitude of floods, enhancing the socio-environmental disasters during the rainy season, mainly in summer."

Urbanization and pressures on natural resources

In Rio de Janeiro city, urban form and their uses accompany the pressures of population growth and economic productivity that generate different resource demands for land, water and energy. The combined effects of these pressures make the city increasingly sensitive to climate change.

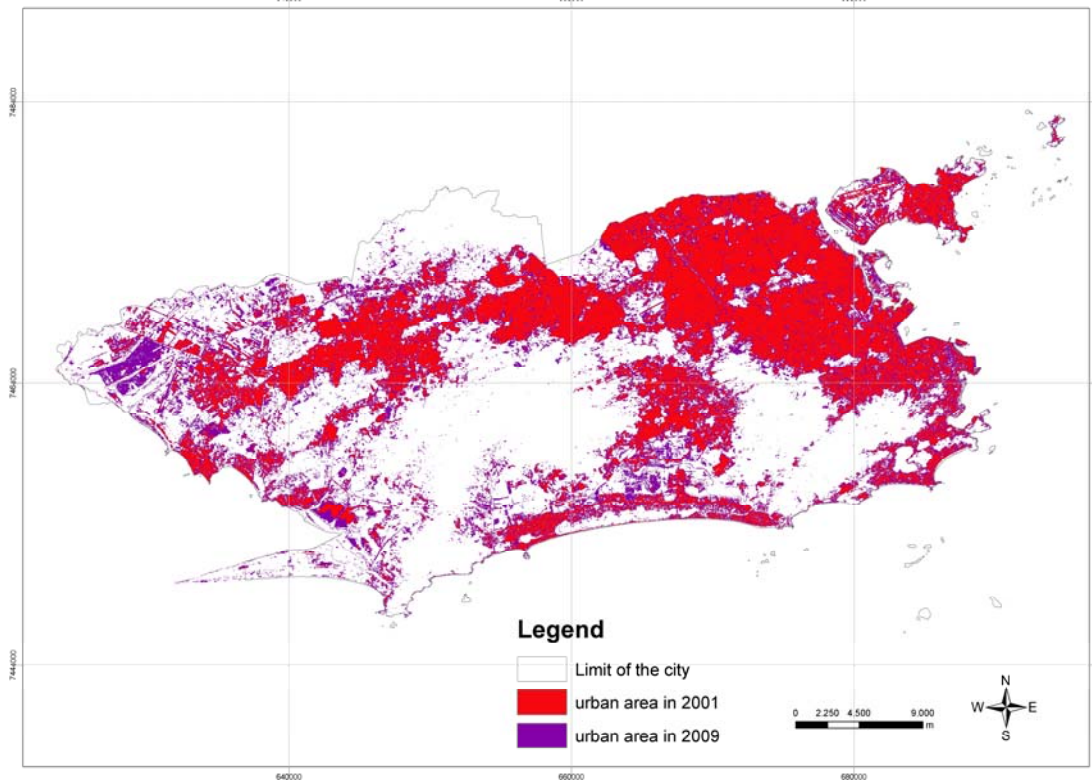
The city has serious problems of social, political and economic inequality. The precarious living conditions of the metropolitan population gathers a group of closely related characteristics: lack of water supply, of sewerage and street paving, illegal occupations, insalubrities of several houses, among others. These characteristics are concentrated in the most popular areas, suburbs and slums.

Over time the occupation of the city was particularly sharp. The urbanization process has resulted in soil sealing, the removal of vegetation, disintegration of the soil's surface layers, pollution of waterways and air, that is, the entire natural system has been altered.

The combination of urbanization patterns, increasing demand for water, energy and land with expected climate change will provide new challenges, particularly with respect to equitable distribution of different resources.

In order to understand the urban expansion, a survey using satellite images (Landsat 5 and Landsat 7 ETM + - orbit point 217-076) was accomplished and it was possible to observe the process of urban expansion in the city between 2001 and 2009 (Figure 1). One may observe an edge effect around the majority of consolidated urban areas in 2001 and the confirmation of the trend of expansion to the west of the city in 2009.

Figure 1: Urban expansion in the city of Rio de Janeiro (2001-2009)



Source: Landsat 5 and Landsat 7 ETM + - orbit point 217-076 – resolution 30mx30m

The consequences of sea level rise

According to Muehe et al. (2007), a series of impacts caused by climate change can affect the city of Rio de Janeiro, being manifested in “changes in morphology and dynamics of beaches, water quality in lagoons, bays and estuaries, balance of the hillsides, and in the survival of mangroves and other plant species.”

“The human planned land occupation itself in other time, under other environmental conditions, may not respond adequately to new meteorological and oceanographic conditions (...) [initially one must consider that] the main causes of sea level rise are thermal expansion of ocean water (eustatic rise) and the melting of continental glaciers.” Then, it is necessary to emphasize that “the level of oceans varies from year to year, in cycles of about 20 to 30 years, with variations from 10 to 50 cm in width, depending on location and time” (MUEHE et al., 2007).

For purposes of urban planning and decision-making processes, more important than a gradual increase is the occurrence of variations associated with meteorological tide⁵. On the values of the meteorological tide, says Muehe (2007), there are the “astronomical tides,” which “can reach amplitude of about 1.30m, ranging in magnitude for different points of Guanabara Bay, Sepetiba Bay and ocean beaches.

Some researchers like Rosman, Neves and Muehe (2007) mention that despite attempts, it is very questionable the simulation of the sea level rise, precisely because it is a dynamic system that varies according to the astronomical tides and mainly to meteorological ones.

Moreover, Mendonça and Silva (2008) point out that “the coastal geomorphology of the Rio de Janeiro is diversified and extremely modified by many factors of natural origin and human interventions. The coastal areas have dynamic characteristics and own specificities that will certainly respond in different ways to the sea level rise”.

Considering the mentioned aspects, we have identified the lower areas of the municipality that would be more susceptible to the sea level rise through the Digital Terrain Model (DTM) generated from interpolation methods (Figure 2).

Figure 2: Vulnerable zones based on Sea Level Rise Risk

Source: Based on Digital Terrain Model (through the interpolation and analysis of topography).

The orange zones correspond to the sea level rise considering the meteorological tide. The red zones represent the increase in sea level considering the meteorological and

⁵ In the open sea the tidal wave would be little affected by climate changes or by a rise of the average level of about 30cm to 1m. In the inner parts of bays and of the estuaries that flow into those bays, however, the rise in sea level would make a tidal wave hit higher points reversals in the direction of rivers leakage”.

astronomical tides (assuming the most critical situation). The areas most affected correspond to locations in the East, part of the South and of the West of the city⁶.

In population terms, the total number of people affected (located at an average altitude of up to 1.50 m) would be about 60.320 or more specifically in the West this number would remain around 5.412; in the South would be 35.557 and in the East around 20.000. In the average altitude of up to 3 m there are 402.849 people.

Currently low areas of old lagoons and inlets grounded, as well as terraces or fluvial-marine plains already represent areas at flood risk due to proximity of groundwater, to the outcrop of groundwater and to the consequent difficulty of drainage.

With regard to coastal erosion⁷, vulnerability increases with the degree of exposure to wave. But, more negative effects than those envisaged for the erosion of the shoreline⁸, will be felt in the groundwater level rise, in the flood of low areas and consequently in the blockage of leakage of channels and rivers of the lowlands whose drainage can barely fit to the present sea level, resulting in flooding conditions of heavy rainfall, in a situation of “spring tides”⁹ and during periods of rise by meteorological tide. In other words, any of the scenarios of sea level rise will bring serious problems, but spatially extended and with greater number of people affected.

The variations of the average sea level and its impact on mangroves¹⁰ due to climate change are another concern. In this case, the main function attributed to these ecosystems would be the stabilization of the shoreline to prevent its erosion and the silting of the same adjacent water bodies. Due to the position of mangroves in the intertidal zone, these ecosystems will inevitably and significantly be affected by changes in sea level.

Risk of flooding

Due to geomorphologic, geological and hydrological characteristics present in Rio de Janeiro city and to human interventions on their water courses as well on the land use, there are varieties of risks related to flood events.

Floods are natural phenomena that occur mainly during the summer rains between December and March, time when it is common the occurrence of intense rain events in late afternoon or extended by the duration of cold fronts during three or four days.

In relation to different types of processes of floods that may affect communities and improvements in the area of the municipality of Rio de Janeiro, one of the risk scenarios that

⁶ The most affected portions of the East would be the harbour and Governor’s Island. In the South, which is constituted by a vast area that spreads from Jacarepagua Lagoon to Barra da Tijuca, the Aterro do Flamengo appears as the most affected area. It is observed that there is in these regions the Galeão and Santos Dumont airport, Marina da Gloria, as well as the whole cove (small bay) of Flamengo and Botafogo. The West part of the city brings together the regions of Bangu, Campo Grande, Santa Cruz and Guaratiba (in Sepetiba Bay).

⁷ Erosion is a function of water movement by waves and currents, thus it would be necessary to distinguish different environments in terms of exposure.

⁸ The shorelines can be classified as exposed, semi-exposed and sheltered.

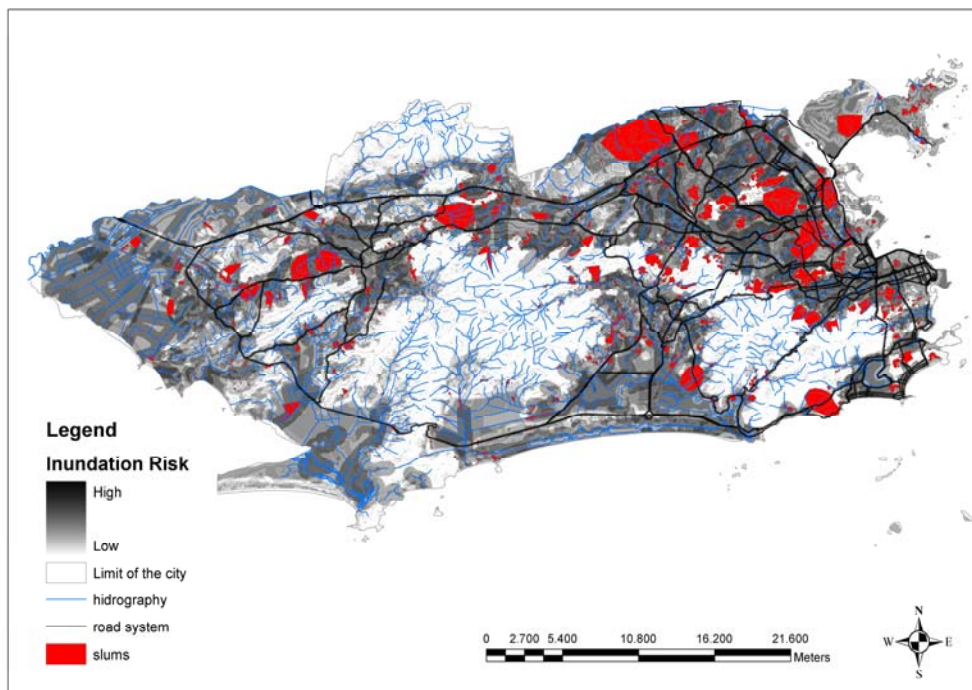
⁹ Twice each month, the earth, moon and sun line up, or come into conjunction, once when the moon is between the earth and sun (new moon), and once when the earth is between the moon and sun (full moon). When the earth, moon, and sun are in conjunction their forces align. The result is a greater distortion of the water envelope. This makes for higher than average tidal ranges. These are called 'spring tides'

¹⁰ The remnants of mangroves of Rio de Janeiro are distributed in three main systems: Guanabara Bay, Jacarepaguá Lagoon System - Barra da Tijuca and Sepetiba Bay, in addition to a small spot on the beach of Grumari and a narrow strip in points on the margin of Rodrigo de Freitas Lagoon (coming from replanting).

deserve to be highlighted is that resulting from processes that affect large urban areas of the coastal plain.

The mapping of vulnerable areas to floods in Rio de Janeiro reveals more clearly the situation of the city (Figure 3). For the identification of these areas, data on land use, protected areas, hydrographic network, soil suitability, road system and topography (Digital Terrain Model) were integrated through GIS providing the identification of the vulnerable areas, i.e., those areas subject to damage from flood events.

Figure 3: Vulnerable zones based on flooding risk



Source: Based on integrated analysis of topography, hydrographic system and land use data

Concluding Remarks

Many of the socio-environmental problems that occur in Rio de Janeiro have shown that this city was developed above the conditions of absorption of the impacts of arising from urban structure, transforming the landscape over time and endangering the population. Urban growth has resulted in a set of systematically interrelated processes that have caused such transformations.

The option of predominant development contributed to the consolidation of irrationalities in the land use, turning valley bottoms into avenues, protected areas in urban lots, wetlands and coastal plains in disorderly neighbors, disrespecting the territory and its natural features.

The challenges are precisely in these problems which concern either the construction process of urban space and, therefore the different political and economic options that influence its settings, or in urban life conditions and social aspects that inform the ways of life and the inter-class relationships.

In the face of continuing urban vulnerability and climate change challenges, there is an urgent need to strengthen social-environmental assessments for adaptive management, in order to better understand the types of climate hazards to which various population groups and systems are vulnerable, the causes of vulnerability, and their location. In this context, the strategy towards mitigation and adaptation should be addressed for identifying the main issues in an integrated social-environmental assessment.

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Section Three: Ecological/Physical Science and Engineering Viewpoints

Chapter 6: Reconciliation ecology in coastal megacities: towards a pragmatic framework for sustainability and resilience

Robert A. Francis

Coastal and estuarine ecosystems around the world cover only 6% of the global surface, yet they contribute almost 38% of the total estimated global value of ecosystem services (Costanza et al., 1997). The resources and services they provide, both ecological and societal, have historically made them ideal locations for settlement, and more recently for major urbanisation. Of the 30 largest global urban regions (based on total population), 17 are coastal, including 6 of the top 10 (Tokyo, New York City, Mumbai, Manila, Jakarta and Shanghai; Fig. 1). Both extensive and intensive urbanisation around estuaries leads to significant degradation of coastal ecosystems, and represents an important environmental issue partly because this in turn leads to a loss of resources and services, and also because such systems are not well understood ecologically. Most work on urban ecology has focused on the terrestrial components of urban landscapes, because these are 1) better understood and easier to monitor and manage, 2) are used (and 'perceived') to a greater extent by urban residents and therefore more likely to be priorities for ecological improvement, and 3) the development of urban ecology from natural history has created a tradition of focusing on the terrestrial urban, with 'aquatic' urban ecosystems being subject to relatively little attention, particularly coastal systems (Sukopp, 2002, McDonnell, 2011).

Urban estuaries and coastal ecosystems are often examined within the context of elevated urban water and sediment pollution and the ecological and societal implications of this. Notable examples include the Hudson River estuary in New York City (Feng et al., 1998) Sydney Harbour (Birch and Taylor, 2000) and River Thames in London (Attrill and Thomes, 1995). However, this is only one facet of the environmental degradation that such systems experience, and in many ways is one of the easiest to mitigate: sufficient improvement and regulation of main polluters (often industry or sewerage systems) can rapidly lead to improvements, as demonstrated in the recovery of aquatic fauna in the River Thames since the 1960s (Francis et al., 2008). Far more difficult to mitigate or restore are losses or disruption of ecosystem components and processes that influence biodiversity and ecosystem functioning, often via extensive hard engineering of bank and shore areas to prevent flooding. Such modifications often involve (for example) the physical removal of riparian or saltmarsh landforms (and associated ecological communities) and the interruption of sediment erosion and deposition dynamics that provide necessary habitat for intertidal estuarine species (Francis, 2009). The continued intensive use of urban coastal and estuarine ecosystems, particularly in major cities, means that pressure on the system is never (or rarely) relieved and so space does not become available for any true form of rehabilitation, particularly at the landscape scale, which is where interventions may be most effective (Brierley and Fryirs, 2009; Francis, 2009). Continued and intense human use also means that estuaries are not just recipients of environmental pollutants, but may also act as sources of environmental degradation for inland terrestrial and aquatic systems, for example via the spreading of invasive alien species, many of which are introduced via ports (Leppäkoski et al, 2002).

A pragmatic interpretation of coastal ecosystems incorporated into global cities is that any ecological improvement must work within the limitations of the existing infrastructure: an infrastructure that will be placed under more pressure in the future as urban populations grow in many areas (UNFPA, 2007). Both 'sustainability' and 'resilience' are frequently stated as desirable aspirations for society, particularly in relation to anthropogenic systems such as cities (Bithas and Christofakis, 2006). Both are used as panaceas to cover a range of developmental aims and strategies, though they are often either ill-defined and superficially applied or highly discipline- or context-specific. Ecologically, urban sustainability may broadly be considered the maintenance or improvement of ecological quality (in terms of ecosystem functioning and services) alongside economic and social development – i.e. the latter should not be detrimentally affected by ecological sustainability. 'Resilience' should not be thought of in engineering terms (which is effectively resistance or stability, i.e. the ability of a system to withstand disturbance without altering its state), but rather ecological resilience, which is the capacity of a system to change state in response to disturbance, but still maintain its functional integrity (Holling, 1996). Therefore, urban regions present a dilemma for the application of classic interpretations of ecology within planning and management frameworks. The dominant conservation paradigm of preserving natural or semi-natural ecosystems, or restoring them, would essentially require a decrease in land/resource use in cities, which would require either a reduction of economic development or more efficient use of resources in more impacted sections of the city. While the latter is possible, and (where feasible) reservation and restoration may be very useful strategies, this has the disadvantage of increasing the contrast between 'green space' and the 'built environment'. This is the approach adopted in much urban landscape planning, based on the principles of landscape ecology, such as the conceptualisation of green (or blue) islands and corridors, though this has shown mixed applied success (Ignatieva et al., 2011). Such systems may also not prove resilient, as there is limited capacity for change (as essentially flows may easily be interrupted, and the system is being 'held' in place).

Instead of this, the pragmatic approach is to consider urban ecosystems (including estuarine and coastal systems) as further constructed components within a manufactured environment. Even remnant systems are heavily impacted by urban environments, and there should be more of a recognition that it's not possible to preserve or 'put back' what has been lost, but rather to create new ecologies that fit with our constructs. Ecological engineering of the built environment will maximise habitat area and potential diversity, increasing both sustainability (as ecological quality will increase without compromising other forms of sustainability) and resilience (as a shifting habitat mosaic will be formed, allowing species to move in response to environmental change). This aspect of ecological engineering fits well within the paradigm of reconciliation ecology (Rosenzweig, 2003), which is defined here as 'the modification of anthropogenic systems to support biodiversity without compromising direct use' (Francis, 2009). This fits well with the concept of sustainability, as one of its key characteristics is that the societal use of the system should not be significantly compromised (e.g. engineered buildings should still be liveable, comfortable and efficient; waterways should still provide societal and economic services as well as ecological). This paradigm is in its infancy but is developing rapidly, despite some criticisms regarding its pragmatism (such as it being labelled 'resignation ecology' by detractors; Holt, 2004).

Application of this principle to heavily engineered estuarine and coastal systems would involve the ecological engineering of infrastructure and associated artificial habitat. It has already been established that artificial habitats in urban estuaries, for example flood defence walls, support different spontaneous species assemblages than more natural structures (e.g. People, 2006; Francis and Hoggart, 2009, in press; Jackson, 2009). Consequently, the ecological engineering of such artificial habitat may focus on 1) varying artificial structures to encompass a wider range of species, and 2) specifically engineering structures to provide habitat for certain species or functional typologies that are desirable. Examples include the installation of ledges, ridges, organic materials or soil modules to walls to create opportunities for plant and invertebrates to colonise (e.g. Francis and Hoggart, 2008), or the direct simulation of habitats such as tidal rock pools (Chapman and Blockley, 2009). Such forms of habitat improvement may increase the spontaneous diversity found on such artificial habitat, i.e. maximising the potential diversity that is moving through the system but which is unable to find expression – potential diversity often being particularly high in urban regions due to the sheer volume of organisms found there ('mass effect'). Other forms of ecological engineering include the construction of 1) floating islands that act as habitat for birds, plants and invertebrates (Hancock, 2000; Kelly and Southwood, 2006; Francis et al., 2008) while also simulating coral reef structures in their submerged sections (Nakamura et al., 1997), which may in particular support fish species; and 2) large wood or other physical features that create underwater habitat and variability (e.g. of flows or sediment accumulation) in the aquatic environment (Larson et al., 2001; Stewart et al., 2009).

In each of these situations there are several key ecological principles that may be followed to maximise the effectiveness of the design, though much of this remains untested. These are 1) species/area relationships, wherein a positive correlation exists between habitat area and the number of species that it can support, though the strength of the relationship varies with taxa and scale (e.g. Rosenzweig, 1995, 2003); 2), habitat contiguity and connectivity, whereby both longitudinal and lateral connections and gradients are maintained, allowing flows of both species and other ecosystem components (e.g. water, sediment) to move between locations; 3) physical (3D) complexity, which is linked to diversity at a range of scales (e.g. Kostylev et al., 2005), and is essentially a product of increased surface area of habitat as well as the creation of a greater range of niches within an area; and 4) habitat heterogeneity or variation of habitat types within a given area (Tews et al., 2004).

As an example of this, extensive areas of constructed inter-tidal foreshore or flood defence structures that present longitudinal and lateral connectivity, a gradient of inundation, physical surface and 3D complexity, and some heterogeneity of structure or material, should be most supportive of a wider range of species that fill various functional roles within the urban estuarine ecosystem (Francis and Hoggart, 2009).

Often such forms of ecological engineering may be achieved without a great deal of compromise, for example in utilisation of a waterway or the physical integrity of a wall surface. Research into this form of urban reconciliation ecology remains in its infancy however, and there is increasing need for interdisciplinary investigations to determine what the potential benefits (and problems) may be with the implementation of such a management strategy at a range of spatial and temporal scales (Francis and Hoggart, 2008; Francis, 2011; Francis and Lorimer, 2011). For example, it is likely that a threshold exists at which such interventions may help to

support species populations and maintain regional biodiversity, but below which uncoordinated efforts may be ineffective (Goddard et al., 2009). In particular progress in this area will require ecologists working with engineers but also something of a change in perception amongst environmentalists, so that an understanding that a functioning, dynamic and resilient system is the most desirable outcome, rather than the re-creation of a particular system. Urban reconciliation ecology may be unpopular as it implicitly requires some level of continued management, but this is a standard feature of urban areas and environmental management should just be considered as one aspect of urban development. Legislative requirement or encouragement for including ecological designs in both terrestrial and aquatic infrastructure, such as exists to a limited extent for urban living roofs in some regions (Francis and Lorimer, 2011) would help to force some of this development.

Key research areas:

- Establishing which ecological designs are most supportive of biodiversity within urban infrastructure, particularly waterways and coastal structures
- Monitoring and investigation of the landscape-scale effects of urban ecological engineering on biodiversity and ecosystem services
- Modelling of response of urban species assemblages to different forms of disturbance or environmental change
- Research into the socioecological drivers of urban biodiversity and services

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Chapter 7: Urban Climate in the Coastal Zone: Resilience to Weather Extremes

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The majority of the world's population now live in cities and many of these are in the coastal zone. Of the world's 20 largest cities¹¹, 15 are in the coastal zone; of the world's 20 densest cities, 13 are in the coastal zone; and nearly two-thirds of urban settlements with more than 5 million inhabitants are at least partially in the 0-10 m above sea level zone (McGranahan et al. 2009). These coastal cities are subjected to hydro-climatic hazards that are natural (ranging from storm surges, tropical cyclones, to heat stress; Table 1) and anthropogenically caused (e.g. air pollution). The magnitude, frequency and spatial extent of these effects vary greatly. Here attention is directed to the hazards generated or exacerbated by the cities and their inhabitants. These affect most coastal cities. Interventions by individuals and institutions at varying levels can be used to enhance resilience to these.

Urban climates

Much has been written about the distinct climates and air quality of cities. Commonly cited examples include urban warming; globally cities are almost always warmer (on average 1-3°C) than the surrounding rural area, though the magnitude of urban warming is highly variable over both time and space; enhanced and faster runoff following precipitation because of increased impervious cover; wind flows channelled by urban canyons; and enhanced precipitation downwind of a city due to increased particulate content, heating and roughness.

These urban climate effects result from changes in the urban surface (the materials, its morphology, the fraction of built and vegetated cover etc) and the activities of the cities' inhabitants as they move around, work and live in the city (generating heat, greenhouse gases, aerosols etc). Careful consideration has been directed to key controls and the spatial scales at which they operate – related to individual properties (micro), neighborhoods (local) and cities/regions (meso-scale) (see Table 2). Grimmond (2007, 2011) provides further details and explanation. This understanding provides a framework for considering possible interventions and key agents and agencies to modify, mitigate or adapt to current and future urban climate conditions.

The special features of Coastal Cities

Coastal cities have additional features that serve to enhance existing urban climate effects and vulnerability to high magnitude hydro-climatic events (e.g. cyclones, etc) and effects of

¹¹ Data analysed from 2011 Largest Cities and 2007 densest cities from <http://www.citymayors.com/>. Coastal location from evaluation of maps.

projected global climate change (sea level rise, heat stress etc). The purpose of this paper is to bring these to the fore.

- 1. Low elevation.** Most coastal cities are located at or near sea level. This makes them particularly vulnerable to coastal flooding, whether due to changes in sea level, tidal waves, or the effects of cyclones or frontal systems. Moreover, many coastal cities are also located by rivers as this provide one source of fresh water and historically have served as access points to interior lands. Given how floods propagate downstream through catchments, this also makes coastal cities vulnerable to flooding from upstream (e.g. current flooding of New Orleans).
- 2. Topography.** Depending on their tectonic setting many, though not all, coastal cities are surrounded by mountains/topographic barriers which serve to enhance precipitation. Weather systems, whether cyclones or frontal systems or just air flowing onland from features such as persistent Trade Winds, interact with these physical barriers resulting in heavy rainfall rates and runoff. Even in the absence of significant topography, changes in surface roughness affect the movement of onshore storms systems
- 3. Land use.** Many large coastal cities are also ports and industrial processing areas. Some of the associated industrial activities, for example oil refineries, result in huge emissions with significant implications for local and regional air quality.
- 4. Sea/Land Breezes.** The proximity of water and land, and the differential heating of these two surfaces over the course of the day, generates day-time sea breezes (on-shore flows of air) and land breezes (off-shore flows of air). In summer, sea breezes are important in coastal cities in mitigating heat stress, though in some urban settings the density of buildings impedes the penetration of the sea breeze reducing ventilation, with implications for thermal stress and air quality. In Tokyo, for example, the city is considering removing buildings to allow the sea breeze to penetrate and provide this ecosystem service. Other cities are considering the orientation of the buildings (e.g. Hong Kong, Singapore); this needs to take into account both wind flow and solar gain (e.g. Ng et al. 2011). Sea/Land breezes also serve to concentrate and re-circulate pollutants across coastal cities with important implications, particularly at night when the urban boundary layer (and thus atmospheric mixing) is diminished.
- 5. Population density.** Coastal cities because of large populations and limited availability of land for residences (in part because of competing other land uses and topography) tend to be very dense. As noted above 13 of the densest cities world wide are in the coastal zone. Thus coastal cities tend to have a high fraction of impervious cover (which enhances flooding). The high fraction of impervious spaces/low fraction of greenspace is also a key determinant of energy flux partitioning – latent heat fluxes (evapotranspiration rates) are suppressed, while sensible and storage heat fluxes are enhanced. This results in greater heating of the air and substrate. High population densities also lead to large anthropogenic heat flux densities (emissions by humans). All serve to exaggerate urban effects, particularly urban warming.

Scales, controls and interventions

Understanding the factors that control the vulnerability of a particular city to urban climate effects and to weather extremes, and the scales (in space and time) at which they operate, provides a physical framework for considering resilience. The challenge is, of course, to map these to appropriate scales of human systems, or actions and interventions by individuals and institutions. Table 3 provides two examples – for heat stress and flooding – the key controls and processes at different spatial scales are identified.

While we can engineer against certain conditions, resilience for the most extreme events requires forecasting so that appropriate response can be taken. For example, for any meteorological event forecasts are generated by numerical modeling. Forecasts are improved by assimilating data and by approximately modeling the urban area (Grimmond et al. 2011). From a measurement perspective this means developing a nested observational system around the large urban area. For example, the Shanghai Multi-Hazard Early Warning System requires co-operation between different provinces in China to allow the instrumentation to cover a sufficiently large area upwind to be provide useful data for assimilation (Tang 2006, WMO 2007).

For low magnitude but high frequency events, for example, exposure to air pollution, it is also key to link measurement and modeling for the specific region and conditions (e.g. sea breeze, boundary layer height, day of week, time of day, emission sources into account) and communicate that rapidly to those who are vulnerable (e.g. Air Alert <http://www.airalert.info>; Air Text, <http://www.airtext.info/>).

To build resilience we need to improve observations, modeling, data use, tools, knowledge exchange and understanding in tandem (Table 4, Grimmond et al. 2010, NAS 2010). Given meteorological hazards occur at both ends of the frequency spectrum, high/low frequency/magnitude, to predict and inform those vulnerable requires a multi-agency approach (e.g. Tang 2006).

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Table 1: Natural hazard in order of decreasing number of deaths in USA (1970-2004) (Borden and Cutter 2008). The majority of natural hazards are directly or indirectly weather related. Many are driven by synoptic scale forcing so given a coastal mega-city location there is (or not) a high probability of an event (e.g. hurricane/typhoon areas)

Natural Hazard ordered by decreasing number of deaths in USA (1970-2004) (Borden and Cutter 2008)	Urban influence ↑ Increased ↓ decreased	Weather related (W , w – to a lesser extent)
Heat/Drought	↑UHI	W
Severe Weather (e.g. fog, hail, wind, rain)	↑Greater roughness ↓Warmer T	W
Winter Weather	↑ warmer conditions enhance precipitation ↓Warmer T more rapid melting (but may lead to flooding)	W
Flooding	↑Greater impervious area	W
Tornado	Roughness steers storms	W
Lightning	↑Enhanced uplift	W
Coastal (e.g. storm surge, coastal erosion)		W
Hurricane/Tropical Storm		W
Geophysical (e.g. earthquakes)		
Mass movement (e.g. avalanche)		w
Wild Fire		W

Table 2: Controls on urban climate are dependent on location as well as urban specific characteristics (modified from Grimmond 2011)

Variable	General controls	Urban controls/effects
Incoming solar radiation ($K\downarrow$)	Latitude; Synoptic conditions/ cloud cover	Air quality/Industrial sources influence scattering
Outgoing solar radiation ($K\uparrow$)		Surface materials; Surface morphology/geometry
Incoming long wave radiation ($L\downarrow$)	Synoptic conditions/ cloud cover	Air quality/Industrial sources affect absorption
Outgoing long wave radiation ($L\uparrow$)		Thermal properties of materials; Radiative properties; Surface morphology/geometry
Net all-wave	Latitude; Synoptic conditions/	Materials, Morphology, air quality

radiation (Q^*)	cloud cover	
Sensible heat flux (Q_H)	Temperature gradient; Atmospheric stability; Synoptic conditions	Building volume; Built fraction
Latent heat flux (Q_E)	Moisture gradient; Atmospheric stability; Synoptic conditions	Fraction greenspace; Irrigated surfaces; Enhanced runoff – fast removal of surface water; Detention ponds etc
Storage heat flux (ΔQ_S)		Materials & morphology urban surface; Orientations walls; Mass/volume urban surface
Anthropogenic heat flux (Q_F)	Latitude; Continentality; Regional setting	Heating/Cooling requirements; Industrial activity; Socio-economic conditions; Population/Building density; Transportation routes & methods
Air temperature	Latitude; Continentality; Regional setting	Materials & morphology of urban surface Release of anthropogenic heat; air quality; m
Humidity	Latitude; Continentality; Regional setting – proximity to water bodies	Reduced vegetation; Fewer moist surfaces Localised releases (industrial sources) as bi-product combustion; Urban air temperature
Wind field	Synoptic conditions	Building & Tree density; Morphology buildings & roofs affect roughness & displacement lengths, Channeling through urban canyons
Precipitation	Latitude (solid, liquid); Synoptic conditions; Topographic variations	Air quality/industrial-traffic sources ->cloud condensation nuclei; Roughness elements/surface heating -> convection

Table 3: Key controls for heat waves and flooding at different scales with attributes of the biophysical environment that can be altered to mitigate or adapt.

	Heat Waves	Flooding
Micro-scale Individual property	Building materials -> change albedo, heat conduction Release of anthropogenic heat (energy use)	Impervious/pervious fraction Retention storage to slow peak Link of guttering to pipe system or not Pre-cursor soil moisture
Local scale Neighbourhood	Areas with similar building densities, vegetation, areas of similar UHI Building materials, size of properties Heights of building, widths of roads	Water bodies/Detention Ponds Pipe networks, Green infrastructure
City/Megacity	Areas that upwind/downwind, Parks, CBD, Sources of anthropogenic heat (electricity, gas etc)	Enhanced roughness, Enhanced heating Enhanced aerosols
Meso-scale Region	Setting, ocean influence, flat, hilly, blocking mountains	Orographic precipitation
Synoptic	Weather patterns, Fronts	Precipitation patterns River network
Global	Global climate, NAO, ENSO, etc, Climatic indices, Climatic variability	

Table 4: High Priority recommendations from the World Climate Conference 3- Need for more sustainable cities: information for improved management and planning of cities (Grimmond et al. 2010, NAS 2010)

Observations	<ul style="list-style-type: none"> • Need for more operational urban measurement station and networks; this will require stations within the urban area and upwind. Station should to be sited and equipment exposed in conformity with WMO Urban Guidelines⁶. Stations are especially needed in rapidly developing cities in hot climates and in their surroundings. Both simple and complex topographical settings should be represented. • Where possible vertical profiles of physical and chemical variables should be sampled. • Long term measurement stations should be preserved or established in cities with different urban morphologies to determine universal flow and flux characteristics.
Data	<ul style="list-style-type: none"> • Need to establish an international data archive to aid translation of research findings into design tools and guidelines for different climate zones and urban land-use. The archive should consist of high quality data of use to a broad range of practitioners. • The importance of fully documenting urban station metadata (e.g. description of instruments, site, data quality assurance and control, protocol) should be stressed
Understanding	<ul style="list-style-type: none"> • Need to develop methods and frameworks to analyse atmospheric data measured above complex urban surfaces. • Proposed actions to make cities sustainable need to be assessed to determine at what scale interventions are needed and are possible. • Need methods to distinguish between signals attributable to urban climate change and those to regional and global change.
Modelling	<ul style="list-style-type: none"> • Need to improve short-range, high-resolution numerical prediction of weather, air quality and chemical dispersion in the urban areas through improved modelling of the biogeophysical features of the urban land surface and consequent exchange of heat, moisture, momentum and radiation with the atmospheric urban boundary layer. • Need to improve or incorporate data assimilation from meteorological and biogeophysical observations from improved observing networks.
Tools	<ul style="list-style-type: none"> • Need to develop tools to allow models to be able to accommodate the wide differences in data availability (e.g. routine versus research intensive data) depending on the application from research to operational situation. • Need to develop tools that allow probable impacts of proposed sustainable design measures to be assessed and ranked, including any unintended consequences of the proposed changes.
Knowledge	<ul style="list-style-type: none"> • Need to ensure widespread education of the meteorological community (including National Meteorological and Hydrological Services, NMHS) about urban meteorology. • Assist NMHS to appreciate the role of meteorology and hydrology in urban planning and management of more sustainable cities of all sizes. • Communication across scientific disciplines and spatial and temporal scales must be encouraged.

Chapter 8: Addressing Coastal Conundrums

by T. Schlurmann¹²

Megacities in the coastal zone as well as coastal and marine ecosystems are subject to multiple and ever increasing stresses from local patterns of climate change and other forms of disturbance resulting from human activity. Addressing this coastal conundrum to deal with and resolve competitive interest of stakeholders mainly in terms of ecological protection and economic growth is one the grand challenges in sustainable coastal research today.

The stipulation of flood safety in urban agglomerations within the coastal zones is of chief importance in densely populated deltaic regions belonging to the most imperilled areas worldwide in the consequence of climatic changes and other triggered effects. Traditionally, Coastal Engineers place strong emphasis on prevention, i.e. taking cost-effective structural measures based on state-of-the-art Engineering knowledge in advance that aim to prevent coastal disasters and help limiting detrimental consequences and losses. Typical Engineering physical approaches to managing coastal flood risks under conditions of sea level rise integrate upgraded coastal defense systems by means of construction, raising or even realignment of physical barriers to flooding and coastal erosion, e.g. dikes and storm surge barriers. Other representative measures encompass reducing the energy of near-shore waves and currents, including beach nourishment, offshore barriers, energy converters (that may also be used for renewable energy generation) and other near-shore morphological modifications. These mostly preventive, yet structural measures are accompanied by added resilience-building strategies based on the modification of existing, exposed settlements and infrastructure, and on the reduction of socio-economic vulnerability, although the latter approaches are seen conceptually less straightforward and more difficult to evaluate economically, but are in any case considered important elements in updated response strategies where coastal systems face increased levels of risk rather than existential threats.

These approaches reflect the Coastal Engineers' long-established and in large parts validated view of an effective flood risk management strategy and also governs novel policies to cope with changes in the coastal zones. Flood defense structures and management schemes are key elements to protect and, in consequence, sustain society living in megacities in the coastal zones from large-scale floods in the long-term. However, public debates tend to disbelief whether these Engineering approaches hold true and are still the best known protection practices along with queries how future strategic responses on the coasts might be designed alternatively. Yet, it is without any doubt that climate and land use changes due to unconstrained growth of urban agglomerations and triggered consequences, i.e. cascading effects and financial burdens, pose new challenges upon the development of megacities in the coastal zones and address integrated research on new methodologies in which urban regions, its society and critical infrastructure can be sustained.

In this regard main demands in R&D and research questions in coastal zones as well as open gaps in Coastal Engineering today address:

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- (1) Improving the robustness of predictability or at least discovering provisional margins of the (up-to-date known) coastal processes and modeling uncertainty of the impacts of global change on coastal zones and ecosystems and how to establish new modular systems to better mimic the effects and responses of the coastal environment, e.g. by creating new *integrative models* by coupling hydronumerical codes simulating near-shore waves and currents with numerical tools estimating erosion potentials and sediment transport rates with family of models to simulate nutrient fluxes, marine growth and changes in ecosystem services in coastal zones.
- (2) Developing and promoting the intelligent and efficient use of land- and water resources management approaches in river Delta areas in order to contribute to climate change protection in these especially vulnerable regions. Research encompasses transdisciplinary fields of water quantity and water quality (sea level rise scenarios, assessment of salinity intrusion, coastal water turbidity, water quality parameters, pollution scenario models), land – and water resources management (innovative land use methods, land use change modeling, wetland degradation, habitat transition, IWRM, LWRM and coastal zone management concepts for improved regional and urban water management); urban development (settlement type analyses, climate change resilience, modeling future spreads and migration, water and land consumption, climate change protection infrastructure), risk and vulnerability (socio-economic analyses, modeling, climate change resilience), urban planning and environmental scenario modeling and projection must be generated, and integrated into adapted and partially newly engineered software prototype Information System and DSS environment, which supports end users and managers in their integrated regional planning processes.
- (3) Developing innovative, transdisciplinary methods in the fields of environmental informatics, remote sensing, hydrology, in-situ measurement network design and monitoring network installation, risk analyses, socio-economic assessment, and knowledge-based service provision via innovative Information System components, specially engineered and tailored for practitioners, i.e. coastal management purposes.
- (4) In terms of integrated research on disaster risks (IRDR) in the aftermath of the recent events in Japan have highlighted the need to redirect and focus on natural-hazard triggered technological accidents (NATECHS) which have been (too) often denied and not fully recognized as an emerging risk in order to clearly determine *cliff edges* for cascading or concatenated hazards taking place in megacities in the coastal zone.
- (5) Further aspects in focus tackle quality assessment on technical measures dealing with adaptation, how to best fit DRR measures and climate adaptation strategies and how to integrate risk assessments studies into policy-making and planning, i.e. mainstreaming of best practices and measures as well as disseminating locally experienced lessons learned.

Yet, Coastal Engineering approaches by tradition notwithstanding place emphasis on customized flood defense systems tailored to local circumstances to protect lives and livelihoods from large-scale floods. In practice coastal management of the future will incorporate multiple structural approaches, including traditional defenses, managed realignment and abandonment of preventive coastal structures and elements. These measures will be broadened by more pro-active measures, i.e. by eliminating structural causes of coastal disasters, e.g. by enhancing building codes or

restore spatial planning efforts in flood-prone areas, and by re-strengthening efforts on preparation (e.g. contingency planning, awareness raising), response (enhance technical response teams) and recovery (strengthen relief and humanitarian aid) following the safety chain approach¹³.

By doing so, [taken from: Ten Brinke et al., 2008] *the consequences of possible flooding would be better taken into account and the policy focus would shift from managing the probability of flooding to managing flood risk.*

¹³ Ten Brinke, W.B.M., Saeijs, G.E.M., Helsloot, I., Van Alphen, J. Safety chain approach in flood risk management (2008). Proceedings of the Institution of Civil Engineers: Municipal Engineer, 161 (2), pp. 93-102.

Section Four: Social Science Viewpoints

Chapter 9: Communicative Resilience in Coastal Megacities

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Potential and Limits of Resilience Thinking

Social ecological resilience concepts, born in response to the challenges of natural resource management challenges, are now migrating to the city and inter-breeding with ideas about reducing vulnerability and mitigating and responding to disaster. This is a positive development because resilience is more than just about recovery or persistence – it suggests that we can achieve a better world by seeking transformative change when ecological, economic, or social conditions make an existing system untenable, to “create untried beginnings from which to evolve a new way of living” (Walker, Holling, Carpenter, & Kinzig, 2004, p. 7).

Resilience thinking is grounded in complex adaptive systems theory, which examines the emergent behavior of large populations of independent, interacting agents. The world is understood as an interdependent and interconnected whole governed by complex and indeterministic processes, which opens up the creative possibilities of achieving resilience through an infinite number of alternative arrangements. This provides a theoretical foundation to examine the capacity of self-organizing behavior within collaborative governance, as opposed to centralized and hierarchical authority.

While this framework is potentially very supportive for supporting social mobilization around a transformative change agenda in coastal megacities, an urban setting also poses new challenges for resilience analysis. Megacities are more socially complex than rural landscapes where resilience originally incubated, and cities increasingly multi-ethnic, multi-racial and multi-cultural character is associated with far greater epistemic diversity (Sandercock, 2003). However, resilience analysis has not addressed these aspects of cultural experience of urban communities, their identity, knowledge practices, and belief systems. Instead, resilience studies have focused on measurable factors external to the subjects being analyzed, positioning the analyst outside the system looking in at those who inhabit it. The goal is to generate causal explanations, even if these explanations range far beyond the simple notions of linear causality.

The value of these explanations is to enhance prediction and regulation, albeit through a more modest approach that has been described as “navigating”, “dancing” or “surfing the change” (Anderies, Ryan, & Walker, 2006; Berkes, Colding, & Folke, 2003). Accordingly, resilience studies focus on biophysical and political-economic transformation, and “...such analyses, framed in terms of utilitarian metrics, frequently fail to recognize that the experienced worlds of individuals and communities are bound up in local places and that the physical changes will have profound cultural and symbolic impacts” (Adger et al., 2009, p. 347). They fail to examine the experiential, contemplative, artistic, and other forms of non-scientific knowledge, what urban planning scholar Leonie Sandercock (2003) calls an “epistemology of multiplicity”, and so have

a limited capacity to understand how dialogue and deliberation can form new identities and solidarities, or provide lay communities with an accessible framework for making sense about resilience.

One reason these “softer” factors are essential to include within resilience analysis is because urban social and ecological components and connections that might prove resilient go beyond resource dependencies and market interactions to include cultural traditions, reciprocal obligations, and emotional ties. This broader set of cultural and symbolic factors frame the way that pathways for adaptation are interpreted and selected, influencing a city’s vulnerability to hurricanes, climate change, reductions in food or energy supply, or any other proximal threat.

More fundamentally, including the subjective experience of city dwellers within resilience analysis is necessary in order to understand and assist communities in deciding what resilience to pursue. This is because in addition to conferring differential advantages, resilience alternatives may also be ontologically and epistemologically incommensurable, grounded in different ways of knowing used by people with differing perspectives and social position. While many resilience scholars have shown that it is possible to generate win-win governance alternatives in rural landscapes (e.g. Olsson, Folke, & Hahn, 2004), these studies of comparatively simple systems have not closely examined the ways that some may benefit from a new system configuration while others may lose, because one group’s resilience may be another’s vulnerability, and resilience at one scale may compromise it at another. Indeed, while efforts to engage in transformative change may be driven by broad recognition of looming threats to sustainability, collaborative efforts are often driven by a committed minority’s dissatisfaction with the status quo, despite its seeming resilience.

Taking identity and subjectivity into account has important implications for dialogic efforts to enhance resilience. Alternative social-ecological configurations may not be readily available to communities, and not just because they lack technical expertise. Understanding the possibilities for transformative change requires self-reflective knowledge of how domination or dependency relationships have shaped their self-interest and subjectivity. People need to become conscious of their role in the reproduction of social practices and the contours of their situated knowledge before they are empowered to transform these knowledges and practices. Engaging in this critical praxis can expand the scope of autonomy and reduce the scope of domination.

Communicative Resilience

Communicative resilience addresses these challenges to achieving the creative potential of resilience thinking. The idea is not just to enhance system guidance through collaborative data gathering and analysis and comparison of alternatives. Rather, communicative resilience is a dialectical process and an outcome of collective engagement with social-ecological complexity. Resiliency conditions cannot be identified before collaborative interaction takes place, in part because the diverse forms of knowledge required to identify preferred system conditions, in part because the capacity to achieve transformative change is reshaped by collaborative interaction. McConney and Phillips (2011) provide an example of this process in their description of the formation of a Caribbean fisherfolk network. Through facilitated dialogue about resilience, fisherfolk came to recognize that their capacity to maintain their livelihood and the health of the

fishery was grounded in developing their self-sufficiency and independence, as well as social and economic equality. Building on relationships established through this dialogue, fisherfolk organized a cooperative network to promote self-management and sustainability.

As this suggests, communicative resilience involves identifying social-ecological system attributes, preferences (“What will we make resilient and why?”), and obstacles to achieving these preferences. As participants deliberate, they develop a common language and knowledge practice that enables them to pursue agreed-upon goals. This process of collective discovery enhances the possibility of transformative change by reshaping both knowledge and knowers, as participants re-examine their ways of thinking, develop new relationships, and revise assumptions from which institutional norms, rules, and practices are derived. The ultimate objective is not only to agree but also to foster mutual reinvention by:

- re-inventing individual as well as collective identity, reinforcing mutual expectations that underpin coordination;
- acquiring new formal and tacit knowledge, both in terms of individual competence and social learning, and;
- developing capacity for savvy intervention to change the institutional conditions of possibility of action.

Narrative Practices

Communicative resilience relies not only on instrumental and tacit learning but also critical and transformational learning, which question and reshape a social-ecological regime. Initiating learning across this spectrum is possible by structuring collaboration as narrative-making or “storytelling”, framing the origins of a resilience problem, how it might be addressed, and by whom. Stories about the past, present, and future have a temporal and spatial context, as well as positioned assumptions and interpretations. These features can encompass and reshape multiple frames and truths, enabling participants to re-examine their ways of thinking and revise assumptions that inform institutional norms, rules, and practices.

Drawing on a rural example with a high degree of cross-scale and institutional complexity, Butler and I (Butler & Goldstein, 2010; Goldstein & Butler, 2009; Bruce Evan Goldstein & William Hale Butler, 2010; Bruce Evan Goldstein & William Hale Butler, 2010) describe how members of the U.S. Fire Learning Network (FLN) drew upon storytelling practices to define fire management’s social-ecological system, their place in it, and its preferred condition. Taking advantage of the availability of federal funding and a willingness to try new approaches after a series of destructive wildfires in the early 2000s, FLN’s coordinators organized hundreds of fire managers around the nation into multijurisdictional, landscape-scale learning cooperatives to develop new, potentially risky, approaches to restoring fire-adapted ecosystems. Within each cooperative, participants described their landscape’s healthy distant past, degraded present, and a future of either continued decline or ecological recovery. This storytelling helped forge a common purpose, develop a shared repertoire of knowledge and skills, and lay the groundwork for cross-jurisdictional collaboration.

In addition, FLN's coordinators publicized exemplary efforts and provided tools for spatial analysis that linked these independent cooperatives at a national scale. Using these tools and a common analytical framework helped them understand one another's stories, and this familiarity gave participants a sense that they shared in the life of a community, despite not knowing all the members of the far-flung network. The FLN's capacity to promote change lay not in the plans it produced but in its capacity to facilitate creation of a new narrative that disrupted old assumptions and habits and engendered new routines that formed the groundwork for institutional change, while enabling the entire network to speak autonomously with a unified voice.

The FLN fostered resilience by building solidarity around a new professional identity, developing skills and knowledge to support that identity, and creating relationships that increased collective capacity. System understanding arose as this potential was developed, rather than being provided by advisory experts. In addition, this reframing was more than just an intellectual challenge, because the long-established national culture of fire management was deeply resistant to change. Collaboration could begin to alter these power dynamics by enhancing each landscape's ability to develop alternative framings, to understand embedded obstacles to pursuing these alternatives, and to begin to reconfigure responsibility and accountability so that change could occur.

Opportunity and Expertise

The FLN was made possible by two circumstances operating at different scales. The first was the opening provided by an immediate crisis, a succession of large destructive wildfires in the early 2000's which got the attention of Congress and led to policy reform and an infusion of new resources through the National Fire Plan. The second was a more gradual condition, the increasing fragility of fire management, a dysfunctional but durable institution whose budgetary commitment and professional dedication to fire suppression still persists despite recognition that most healthy forests need fire, and that fire prevention only increases fire incidence and magnitude, as well as containment costs and community vulnerability. This alignment suggests one context in which communicative resilience can be pursued – a combination of a conventional “shock” like a natural disaster, along with a system approaching a tipping point, where small changes can cascade bringing unpredictable and consequential outcomes. When the status quo is no longer tenable and window of opportunity opens, a small, sustained, strategic intervention can potentially yield a big impact by feeding new perspectives, ideas, stories and frames into the larger system.

However, conditions alone don't determine an effective outcome - taking advantage of this opportunity through collaboration requires planning and collaborative leadership skills. Even shaken institutions can be an obstacle to broader social-ecological resilience, maintaining themselves despite shocks or perturbations that might otherwise catalyze transformation (Allison & Hobbs, 2004), and increasing the chance of catastrophic events and dramatic, unanticipated change (Gunderson & Holling, 2002). It's not easy to organize a group that can shape the conditions for transformative change if these people initially lack cohesion and aren't powerful within the present system, and even powerful people have difficulty in promoting systemic change. This kind of process requires skilled collaborative design and facilitation to help develop

trust and empathy, foster understanding of interdependent relationships, and enhance cognitive capacity. These conditions are the foundation for effective storytelling, the capacity to recognize and give meaning to emerging ideas and patterns. As the FLN case suggests, creating conditions for this to occur in multiple collaboratives and integrating them in a network is even more challenging.

Building off the issue of power disparities and the need for critical learning, facilitators need to draw on a wider array of collaborative design principles than those developed to promote stakeholder-based consensus, such as neutrality, transparency, and maximum inclusivity (Innes & Booher, 2010). They also need to consider how to operate in more agonistic settings, to assist participants in acquiring the ability to challenge powerful actors and hold them accountable. Collaboratives may need to operate effectively in the political margins, using techniques that are less state-oriented and managerial and more akin to social movements. For example, Bullock, Armitage, and Mitchell (2011) describe how a “shadow network” worked in relative secrecy to develop ideas for land tenure reform that challenged the primacy of Canadian provincial government, labor groups, and timber companies. This network promoted resilience by destabilizing an inequitable and harmful system, creating room for the more locally-controlled alternative that is emerging in its place.

In addition to skilled facilitation, resilience scientists are a critical resource to enhance communicative resilience. However, when resilience experts engage in collaborative processes as apolitical puzzle-solvers they may displace focus from political “what to do” questions to technical “how to” questions, promoting a specific relationship between science and administration while obscuring conflicts over governance (Evans, 2011; Hajer & Wagenaar, 2003). The risk of technocracy can be less if scientists maintain a distinction between their scholarly work and the work of engaging community members in ways that foster autonomy, creativity, and coherence, to enable participants to come to their own understanding of resilience by drawing on their own knowledge and telling their own stories. This requires deference to other forms of knowledge, cultivation of a reflexive awareness of scientific influence, and an openness to critical review by intended beneficiaries. Facilitators can apply joint fact-finding techniques to reduce power differences and incorporate local and practice-based knowledge (Karl & Susskind, 2007).

Coastal megacities may be entering a time of rapid social and ecological transformation, when approaches to governance often fail and destabilizing conditions encourage emergent self-organization. In these transformative times, efforts to enhance communicative resilience may enable more than just prolonging survival by providing an opportunity to explore and enable the many ethical, political, cultural, and ecological possibilities for life.

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Chapter 10: Governing climate change in coastal megacities: towards resilience and transformation?

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Introduction

In this brief note, intended to spark discussion, my intention is to consider how we might understand the governing of climate change in coastal megacities, and the ways in which different interpretations of this process might lead to forms of resilience and transformation¹⁴. Focusing on climate change, of course, runs the risk of missing the very things which structure the possibilities for resilience and progressive transformation in urban lives and places. In this context, it is important to state out that outset that I do not regard climate change as a uniform or predetermined 'thing' which will 'happen to' megacities in the coastal zone, but rather as a set of socio-environmental processes that configure and are configured through coastal megacities. In the remainder of this discussion, I first consider what the 'governance problem' of climate change and coastal megacities might comprise, before turning to outline some of the key elements of the urban climate governance debate and the potential implications for coastal megacities. In the final section, I draw on some of my current research to consider the sorts of climate change 'experiments' that are happening in coastal megacities and their implications for future research in this field.

Considerations of vulnerability, resilience and transformation, or, what is the governance problem?

Within the debate concerning climate change and coastal cities, for good empirical and political reasons, attention has frequently focused on issues of vulnerability to the impacts of climate change, and particularly coastal inundation. Different perspectives have been advanced here, each of which has particular implications for how we understand climate change, resilience and transformation. Stepping into a field which is not your own in such company is always rather dangerous, but this can be briefly summarised as follows. For some, climate impacts are effectively regarded as risks to particular vulnerable locations and pose a threat to assets, lives and livelihoods in these places. Vulnerability can be mapped, assessed, and, in one way or another, insured. Despite sustained critique and some deeply unsatisfactory ways of thinking about what resilience may mean, this perspective retains a curious foothold in both academic and policy debates. For others, climate impacts serve to exacerbate existing inequalities, creating vulnerabilities for the poorest and most excluded in society. Addressing vulnerability and enhancing resilience in this context requires structural and political change. It is in this camp that my own sympathies broadly lie.

There are no doubt other perspectives, and much nuance in these arguments which is not captured here, but in both cases vulnerability, resilience and transformation in the face of climate change is figured in terms of climate impacts, usually considered one at a time. While

¹⁴ To this end, this document does not contain references to the academic literature which has provoked my thinking on these issues, and which would provide evidence to support the claims made. The reader should rest assured that this exists.

researchers have examined ‘cascade effects’ of coastal inundation across urban systems, only limited research has been done which considers the composite effects of multiple forms of climate-related stress on coastal megacities (e.g. heatwaves, flooding, health). Equally, and in keeping with the great divide within climate change studies, considerations of the relation between the direct impacts of climate change and the implications of the growing imperatives at global, national and urban scales to reduce, or mitigate, global greenhouse gas emissions, have rarely been considered. For megacities in the Global North, climate mitigation has had the longer history and the most sustained political attention, although adaptation is increasingly on the agenda. One of the most interesting things about the growing concerns with climate change in megacities (coastal or otherwise) in the Global South is that such divides are increasingly being broken down – think, for example, of work underway in Durban and Cape Town. At the same time, international agencies – particularly UN-Habitat and the World Bank – are increasingly likely to discuss the notion of ‘climate smart’ cities as those which consider resilience and transformation both in terms of decreasing vulnerability to climate impacts and to changing technologies, fuel economies and the politics of low carbon. Here, then, resilience and transformation in coastal megacities are regarded as a matter both of climate adaptation and of mitigation, and which require attention to the ways in which vulnerability is produced through existing structures of political economy operating within and beyond the city.

Governing climate change in the city

A great deal has now been written about the dynamics and challenges of governing climate change in cities. This can be very briefly summarised as follows. Urban responses to climate change began in the 1990s, were focused on small/medium sized cities and the issues of mitigation, and involved the transnational organisation of primarily municipal actors. From the 2000s, a new wave of urban responses can be identified which included mega/global cities and increasingly cities in the Global South, remained focused on mitigation but which also engaged with the adaptation agenda, and which involved new forms of transnational organisation and the engagement of a range of non-state actors, from civil society, international organisations and the private sector. Recent work by Mike Hodson and Simon Marvin explains the drivers for this as a strategic concern on the part of cities for securing resilient infrastructure and investment/economic growth.

However, despite then almost two decades since efforts for urban climate governance began, it remains the case that most of what we might term ‘urbanization as usual’ remains focused on a carbon intensive path, with little regard for the potential impacts of climate change. It comes as little surprise then that there remains a persistent sense of a gap between the rhetoric and reality of addressing climate change at the urban scale; of policies not implemented, targets not fulfilled, and of most of our urban world unaltered by a concern to reduce GHG emissions or to adapt to the impacts of climate change. In this context of a pressing need for urban responses to climate change and uncertainty about the impacts of current efforts, ‘governance’ is frequently seen as both the problem and the solution. We, so the story goes, and this is one I have myself told in various ways over the past decade and more, need to understand how cities are governing climate change, and we need more and better governance.

There are at least three ways in which we might start to address this problematic – of the need for urban climate governance and its persistent failure. The first is the approach which is probably most familiar. In this frame, ‘governance’ is perhaps most often conceived in terms of the need to strengthen our knowledge and institutions for addressing climate change - creating more of the ‘good stuff’ that build social, economic and political organisations. In this story, the problem with urban responses to climate change is that we do not have enough of this ‘good’ governance – in essence, that we *lack the capacity to govern climate change*. To this end, a myriad of institutional issues have been shown to create barriers to the design, development and implementation of municipal climate policy, from finance, to knowledge, to the lack of joined up or integrated government etc. There is nothing inherently wrong with this story of governance as the need for more and better capacity, and indeed it is important not to belie the significant capacity challenges that face many of the urban places across the planet not least the large swathes of coastal megacities that remain marginalised from processes of urban governance, but it only reveals part of the problem.

Rather than seeing the governance problematic in predominantly institutional terms, others have located the persistence of urban climate governance failure in the realm of political economy. In these terms, seeing ‘capacity’ as the means through which to generate more and better urban climate responses misses the fundamental point that more often than not it is the urban political economies of climate change which matter most in enabling and constraining effective action. In some senses, this is a very old story of political conflict and struggle which has been at the heart of urban societies over time, and to which climate change adds a new dimension. At the most fundamental level, struggles have emerged over whether cities should or should not be addressing climate change, particularly in the context of the global south where questions of development, and the right to it, loom large, but also in the developed economies where climate change is seen to pose a challenge to business as usual. However, new stories can also be told. The growing carbon economy – whatever we may think of its effectiveness - may be changing the dynamics between different interests in the city, raising the spectre that growth can be married with development, while at the same time we can see the growing involvement of the private sector in addressing urban climate change and in calling for new forms of protection. In this reading, governing climate change in the city means establishing new logics for the organisation of the state and of the economy, signs of which can already be discerned, and building both public and private capacity to govern. It points us to the important political work there is to do in establishing urban climate governance, work to which knowledge and institutions contribute, but which relies on more fundamentally engaging with private and economic interests while at the same time ensuring that the interests of those for whom money does not talk are not neglected. In this sense, it is a truly political problem.

If the previous two accounts of urban climate governance differ significantly in terms of how they conceive of the urban climate change problem, they are united in one fundamental approach – governance is seen as achieved through actors and institutions who hold some level of authority over others. Power can, however, be accounted for differently. Rather than seeing power as a held capacity wielded over others, some theorists suggests that power is generative – it is made in the process of governing. In this sense, governing may more productively be considered as a project rather than a “secure accomplishment” (Murray Li 2007b: 10). In this account, governing is achieved through the ‘regimes of practice’ held together through particular

rationalities – about what the problem is, how it should be addressed, who should be responsible, as well as a range of strategic and mundane techniques which serve to put this rationality into effect. This is a process which is not confined to the ‘social’ sphere – it requires the assemblage or alignment not only of diverse social actors but of materials, artefacts, infrastructures and so on to achieve the ‘right disposition of things’ within which conduct can be governed in line with programmatic aims. Governance, here, is neither a matter of institutional capacity nor, only, of political interests, but rather is established through determining the nature of the object to be governed and aligning social and material constituents to produce forms of conduct – of institutions, actors, and even the material world – that accord with these aims.

So, what does all of this amount to? It is to suggest that the drivers, and barriers, of urban climate governance need to be understood as three-fold: as matters of institutions; as matters of political economy; and as matters of the urban fabric, the very stuff of the city – of electricity, water, housing, waste and so on. In turn, when seeking to understand the potential, and limitations, of urban climate governance it means that we need not only to examine the institutional, social, political and economic struggles that are emerging within formal arenas of planning, policy-making and implementation, but also to consider the ways in which other interventions in the city – specific projects, initiatives, or what I term ‘experiments’, may also serve as a means through which climate governance is accomplished.

Experimenting with climate governance in coastal megacities

There are then three related generic challenges for governing climate change in order to enhance resilience or achieve transformative change in coastal mega-cities: institutions, political-economies, and the socio-technical systems through which urbanism is made, experienced and reconfigured. There are a number of studies which are now taking place to understand the ways in which processes of plan-making, on the one hand, and community-based responses, often in the poorest areas of such cities, are emerging and the extent to which they may be able to address one or more of these challenges. We can no doubt learn a lot from these cases, and find useful ways of moving forward.

Here, I want to offer something slightly different. In keeping with the idea advanced above that socio-technical systems provide a means through which governing is conducted in cities, it seems that particular forms of urban initiatives – purposive interventions in urban infrastructure networks which seek to innovate or build experience in the city in the name of climate change, or what I term climate change experiments – could provide a critical means through which resilience and transformation can be achieved. In my ESRC *Urban Transitions* Fellowship, such experiments are at the heart of our analysis. We have conducted a desk-based survey of 100 global/megacities, seeking to capture and record as many instances of climate change experiments as we can. This is a very imperfect method. It captures those things that are talked about and recorded (in one of five European languages). It is likely to be biased to areas of the world where web presence and policy materials are taken for granted. Nonetheless, it provides a starting point for considering the activities of a range of actors and multiple sites of intervention through which climate change is being mobilized in such cities.

This database records information about 627 experiments, of which some 315 are in large global coastal cities, and 188 in cities with populations regarded by some estimates as being over 6M. Having only just begun to analyze this material, I am not in a position to consider in a close detail the differences between experiments in megacities and those elsewhere, but perhaps some initial findings might provoke discussion. Of all of the 188 experiments in this sub-set, only 24 are concerned explicitly with adaptation (from a total of 76 in the database as a whole). This is partly a result of what sort of data this database captures, but it is still intriguing that responding to climate change in these cities, and beyond the municipal authority alone, is being framed in terms of mitigation. Intriguingly, only 7 of the experiments captured focus on flooding or coastal protection, suggesting that this may be an arena within which experimentation is not being practiced. However, of those that focus on mitigation, the majority are concerned with urban infrastructure projects – energy, water and waste (56 from 164). There are then, important differences emerging in terms of the nature of climate change experimentation in the mitigation and adaptation domains in these cities, though of course much more analysis is required to establish any patterns and their implications.

Take away

Governance is frequently regarded as the solution to the urban climate change challenge. But it matters very much what that challenge is regarded as being, and how governance is framed. Here, I have suggested that enhancing resilience and transformation requires an engagement with the ways in which vulnerability is structurally produced. Further, governance is not just a matter of institutional capacity, though this is important (and indeed reflective of other dynamics), but of political economy and critically of the socio-technical systems through which cities are configured, maintained and contested. This means that we can not only look for governance responses in city halls, or in new markets or political arrangements, but rather must pay attention to the ways in which resilience and transformation are made possible and obscured through urban infrastructure networks. Our work on climate change experiments suggests that coastal mega-cities are fertile grounds where such experiments are emerging. To date, such experiments appear to be primarily focused on issues of mitigation, rather than adaptation. Interesting questions concern why this is the case, and whether there is something structural about the nature of the problem at hand, or of the state of debate, that is producing such forms of intervention. It will also be important to know who is undertaking such experiments and, of course, with what intent and with what effect. Critically, we must ask whether such interventions are capable of sustaining a just response to climate change in these critical places.

Chapter 11: Syndromes assessment (for interdisciplinary knowledge integration), and critical approaches (that take into account and question power relations) in the context of coastal urban resilience

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Syndromes and interdisciplinary knowledge integration

Lack of knowledge integration in planning and policy-making has long been recognized as an obstacle for sustainable development (UNCSD 1995). While sectorial planning has the advantage of being unambiguous, with clear objectives and a good correspondence to the specialized institutions responsible for implementation, it presents the disadvantage that the assortment of plans and regulations across sectors may have inconsistent and incompatible objectives, and often the issues of sustainability fall between the gaps. Integrated and place-based sustainability science has been proposed for understanding problems arising from multiple, cumulative and interactive stresses, driven by a variety of human activities, with manifestations in specific places. Syndromes assessments can contribute to sustainability science by including the functional complexity and multiple stressors, involved in sustainability problems, in one easily communicable representation which integrates qualitative and quantitative information.

Syndromes assessment is an integrated approach (looking at wholes rather than merely at their component parts). It consists of identifying the complex networks of cause-and-effect of coupled socio-ecological system, such as a coastal urban setting, in order to understand its dynamics. The origin of syndrome analysis is the “syndromes of Global Change” (SGC) approach developed by the Potsdam Institute of Climate Impact Research (PIK). SGC represent a global view on local and regional dynamics of environmental degradation (WBGU, 1997; Ludeke et al., 2004). The replication of functional patterns of human–nature interaction at the global level are identified by global change experts and then illustrated and validated through specific constellations in concrete situations. The basic elements for a systematic description of syndrome dynamics are called symptoms. The term “syndrome” refers to a typical co-occurrence of different symptoms that describe complex natural and anthropogenic dynamic phenomena.

“Syndromes of Sustainable Development” (SSD) are defined as functional patterns of causal interactions in socio-ecological systems, or characteristic constellations of natural and anthropogenic trends of change and their respective interactions, affecting (in negative but also in positive ways) the sustainability of development. Unlike the SGC, the SSD are not limited to the global scale; they can be applied at the national, and potentially also at the local scale; and they are not restricted to “pathologies” as they may also include positive, healthy developments. Syndromes are more than causal networks of specific situations; syndrome analysis is based on the idea that these networks are repeatable patterns that can manifest in different parts of the world. In other words, they represent a generalization of a higher order than a collection of cases. A central question is thus how far it is possible (and legitimate) to generalize.

Building on ECLAC’s experience with the comprehensive assessment of disasters in Latin America and the Caribbean, a syndrome of vulnerability to hydrometeorological disasters was proposed for Central America and the Caribbean (Manuel-Navarrete et al. 2007). The proposed

syndrome suggests the existence of three vicious circles or causal loops increasing vulnerability to hydrometeorological disasters in the region. Two of these causal loops are focused on the dynamics occurring within urban poor areas. They point to the importance of breaking urbanization cycles marked by the absence of effective land-use planning which lead to the occupation of hazardous areas by poor people. Poverty and socioeconomic marginalization is a central symptom closing these loops, which reinforces the generally accepted idea that poverty is a central driving force of vulnerability. Breaking these vicious circles might need to reconsider the economic incentives and planning tools which have proven to be ineffective for avoiding that a large part of the population settles in hazardous areas. The third causal loop goes far beyond the urban context and establishes ecosystem degradation and conversion as its main driving force. This vicious circle supports the notion that vulnerability should be understood in the context of human–environmental interactions. In this particular case, biospheric, pedospheric, and hydrospheric factors are found to be causally related with the economic, social organization and population spheres. Addressing this kind of vicious circle requires the integration of research, policies and institutions which often operate within separate domains in an uncoordinated manner. This causal loop indicates that vulnerability mitigation strategies need to address whole causal clusters rather than focusing on single symptoms.

The syndrome approach is a structural method of analysis that allows detecting critical information shortages, interrelations among subsystems, and entry points for policy intervention. Syndrome representations provide an instant picture which permits the presentation of the biogeographic, economic, social, and institutional dimensions of a situation in a didactical manner. One of the challenges is how to improve the legitimacy and credibility of the representation. The legitimacy dimension is related here with the degree of incorporation of knowledge and perceptions from relevant experts and actors throughout the characterization of the syndrome, while the credibility dimension is related with the fact that a syndrome is a representation of a causal network including both “strong” (well established) and “weak” (more hypothetical) causal links, as well as a structure joining the links and conforming the whole that is often hypothetical.

Taking into account (and questioning) power relations in global environmental change research Social power is frequently absent, merely acknowledged, or narrowly conceptualized in Global Environmental Change (GEC) research. Oftentimes, power is equated with “capacities” to implement policies aimed at weathering external threats. Apolitical or power neutral responses misrepresent GEC as a problem to be solved and/or an environmental issue with a human dimension. This fails to recognize that GEC is not a risk external to humanity, but rather an internally generated phenomenon. Consequently, strategies (i.e., policies) to protect us from ourselves (!) are ultimately paradoxical and counter-productive. Instead, we need critical and historical understandings of the social conditions, including power, under which global challenges were created in the first place. GEC should be seen as an affair which is endogenous to all the dimensions of the human phenomenon, including power relations (Hulme, 2008; Parks and Roberts, 2008; O’Brien, 2009; Okereke et al., 2009). As aptly put in the description of Mike Hulme’s latest book: “Climate change is not ‘a problem’ waiting for ‘a solution’. It is an environmental, cultural and political phenomenon which is re-shaping the way we think about ourselves, our societies and humanity’s place on Earth” (Hulme, 2009). Consequently, we need comprehensive approaches that bring power into the equation. In this vein, social phenomena

such as corruption, opportunism, or greed are as integral and central to GEC as biodiversity, carbon dioxide concentrations, or the melting of the ice caps. Accordingly, responses cannot be reduced to “book-keeping” and rational management of species, gases, or water levels. This is not to say that acknowledging power as a central dimension of GEC would render policy, management, and technology useless or irrelevant. However, it recognizes that they are far too limited because lead one to identify GEC as the problem instead of the symptom of a larger problem which is essentially socio-cultural, psychological and political.

In the “disasters” literature, Hewitt’s edited book (1983) was the first to criticize the apolitical construction of natural disasters and development. Some subsequent theoretical and empirical work defined power as a main root cause of vulnerability due to its effects on the marginalization of certain groups (Blaikie, 1994). Drawing on political economy, this line of enquiry started to dip, although timidly, into the deep waters of social theory in search of alternatives to power-neutral perspectives (Ribot, 1995; Tierney, 1999). In parallel, a few GEC researchers charted a similar critical perspective (Redclift and Sage, 1998; Adger, 1999). Ben Wisner was perhaps the sharpest critic of the power neutral mainstream, which he defined in the following terms: “Most work in hazard research, disaster response and risk assessment assumes the validity of conservative or liberal social theories in which society is believed to be made up of individuals who optimize their perceived interests more or less rationally in the context of institutions such as governments and markets that are more or less successful in harmonizing the interests of large numbers of individuals” (Wisner and Luce, 1993:129). From this early critical stance, the so-called entitlements and assets approach emerged in the 1990s (Watts and Bohle, 1993; Moser, 1998). Unfortunately, this was probably the only significant effort to model vulnerability/adaptation that explicitly considered power-related variables. Thus, even though the reference to social power theories was largely peripheral, the focus on entitlements/assets emphasized the structures constraining and enabling the access to resources of vulnerable groups.

Power-sensitive approaches were enlivened in mid 2000s through Wisner’s re-assembling of the influential book “At risk: natural hazards, people’s vulnerability, and disasters”, which had been first edited by Piers Blaikie a decade before, as well as through new edited books such as Pelling (2003) or Bankoff et al. (2004). At the same time, variations of entitlement/assets approaches emerged under the banners of “fair adaptation” and “putting the vulnerable first” (Paavola and Adger, 2006). The goal was to insert social justice criteria within adaptation regimes and policies. The “vulnerable” are subjected to, and are recipients of, adaptation policies, but are usually unable to influence their design and implementation. Accordingly, the “climate regime” should be modified in order to guarantee equal participation and increase the accountability of the powerful.

Yet, the persistent propensity to categorize local people as “the vulnerable” is not precisely empowering. Likewise, the idea of “incorporating them” into the process (versus creating a joint process, or incorporating “us” into their on-going processes) puts them in a disadvantageous starting position. In the extreme, and a far cry from the intentions of its proponents, the notion of participation may degenerate into what Duffield (2006:70) describes as “the biopolitical incorporation of a species-life [“the vulnerable”] that, lacking the insurance-based safety-nets and welfare regimes of mass [Western] society, is cast as essentially self-reliant; in other words,

‘non-insured’”. In this context; the notions of development, emergency relief, and adaptation policies become “a set of biopolitical compensatory and ameliorative technologies of security that define and act upon non-insured populations to improve resilience by strengthening self-reliance” (Duffield, 2006:74). Thus, advocating the empowerment of “the vulnerable” and keeping a commendable commitment with justice does not necessarily lead to any fundamental revision of the causes of unequal power distribution. In this sense, power, although repeatedly conjured as something important to consider, remains largely foreign to GEC and disasters analysis.

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Chapter 12: Adaptive Urban Governance: Scale Challenges for Coastal Cities and their Planning Processes

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Adaptive urban governance is a key issue for coastal cities in the light of climate change. Yet the discourse on urban adaptation to climate change still focuses dominantly on the modification of physical structures, while the need to change planning and governance processes has received less attention. The presentation reviews climate change adaptation strategies of ten selected cities and analyzes them along the lines of overall vision and goals, baseline information used, direct and indirect impacts, proposed structural and non-structural measures, and involvement of formal and informal actors. Furthermore, the presentation will examine more in-depth scale mismatches that are key constraints within effective adaptation strategies, such as spatial, temporal and functional mismatches. In this context also the various linkages and dependencies between cities and their hinterland need to be better understood in terms of identifying potential conflicts between urban adaptation strategies and their implications for the hinterland. These issues will be illustrated using the case study of the City of Ho Chi Minh and Can Tho in Vietnam as well as Lima in Peru. The comparative analysis of different urban adaptation strategies also shows that the integration of formal and informal actors and actions and limits of conventional urban planning strategies and processes have not sufficiently been taken into account. The paper will conclude with calls for new forms of adaptive urban governance that go beyond the conventional notions of urban (adaptation) planning. The proposed concept underlines the necessity to move from the dominant focus on the adjustment of physical structures towards the improvement of governance and planning tools. First ideas on how to modify also existing planning tools will be outlined, such as the concept of climate proofing for plans and strategies. Moreover, the concept of adaptive urban governance will also acknowledge the need to mediate between different types of knowledge (expert and local knowledge) and to achieve an improved consideration of different measures, tools and norms in order to be able to create synergies between formal and informal adaptation processes particularly in urban agglomerations in developing countries in coastal areas.

Section Five: Key Observations and Conclusions

Chapter 13: Key Observations and Conclusions

The preceding chapters have provided some detail on what we know, and the range of conceptual, methodological and empirical challenges facing the task of better understanding the ways in which urbanization and coastal systems interact, and the possibility of building resilience for human and non-human species that meets the demands of equity and sustainable development.

The following section looks ahead to ask where the priorities lie for advancing the framing, methodologies and impact of research. The need for systematic and strategic work is well demonstrated by Box 1 that presents three myths that continue to influence policy and research in coastal cities – and elsewhere.

Box 1: Three myths and their influence on knowledge and policy

1. *Risk (vulnerability and hazard) is static and spatially bounded.* This is reinforced by the effectiveness of spatially-distributed GIS outputs/products that mostly capture or illustrate one chief parameter or status in static, problem-orientated assessments to support decision making processes, and also by the dominance of spatial (over sectoral) actors – e.g., urban planning and environmental management rather than social services or finance ministry.
2. *Cities are ecologically poor.* There is much scope to provide varied ecosystems from coastal to aquatic, from greening of roofs and buildings to the recognition of streetscapes and gardens or parks as ecological opportunities. These are new environments but need not be ecologically limited in diversity or abundance.
3. *If we have the right information people in power will make the right decisions.* It is not sufficient for science to generate and analyse information on specific problems, the decision-making processes that follow from this, and indeed the scientific processes that generate data also need to be examined to understand why particular pathways for resilience are chosen. Connected to this is the recognition that coastal megacities are not unified entities with a common interest represented by a singular authority: in practice the city is home to multiple, competing interests and visions for what the city and its environment should be.

What do we know?

Existing research and expertise though distributed provides a solid base for identifying the characteristics of a more integrated research agenda. With a particular focus on research undertaken on aspects of risk management, and more recently adaptation, mitigation and resilience in coastal cities, this section outlines nine priorities for comprehensive and integrated analysis. An integrated agenda will benefit from research that takes into account:

1. *Multidisciplinarity.* While there is a good base of discipline specific data there are few examples of systematic and comprehensive assessment or system wide data collection to

examine or model the interaction between social and environmental processes in coastal zones. Large datasets exist (in health, coastal processes etc) but are not routinely investigated.

2. *The social construction of knowledge.* Very few studies have examined the ways in which information, especially on risk, is communicated from science to policy makers and within society. There is some work on early warning systems in developing countries but less on the action of informal social networks, on the politicisation of science and construction of political discourses on climate and environmental change on the urban coast.
3. *Internalize environmental change:* Risk (including climate change) does not simply happen to a city but is configured and reconfigured through a city. This perspective emphasizes the social as a site for mitigation and adaptation activities. This approach also better fits the lived experience of risk on the ground which is multifaceted so that environmental, social, economic and political forms of hazard and their drivers interact and can help better engage people with local and tangible problems rather than the abstract of climate change.
4. *Scale.* It is difficult to assimilate existing datasets from different sources because of the contrasting spatial and temporal scales used for collection and analysis. Applying the concept of “nested scales” may provide some scope for structured coupling between processes acting at different scales.
5. *Local orientation.* We have good aggregated data, especially on global physical processes, but this is of little use in local risk management. Downscaling will help but there is also a need to support local data collection and methods that can integrate form dos data at the local scale to produce rich descriptions of status and process.
6. *Vertical space.* This includes data on the atmosphere, coastal and riverine aquatic systems and sub-service geography including temperature, chemical and water flows and biota. The interaction between the atmosphere, land, soil and water is accentuated on the coast and urban contexts introduce additional pressures and substances that can feed back on urban human and wider ecological and physical resilience.
7. *Dynamic processes.* The multiple-overlapping temporalities that converge in coastal urban systems (from daily commuting to tidal phases and global economic cycles) make this an intensely dynamic context for research and policy. Most risk management and development studies generate static data in various dimensions (socio-economic, environmental, geodata, etc.). There is less consideration of dynamic features or intrinsic processes leading to system changes, i.e.: new infrastructure that triggers local urban migration patterns. Resilience requires that the dynamics of a system, interrelationships and change are given greater priority. It will always be important to describe contemporary elements, but resilience planning requires greater emphasis on recording and tracking dynamic social, ecological and physical processes
8. *Comparative social context.* We know something of the role played by governance systems, technology transitions and social stratification in shaping geographies of vulnerability and

resilience in individual cases, but there has only been limited comparative work. There is also little work that connects local proximate causes of vulnerability or resilience with wider systems structures operating at the city or world scales.

9. *Urban regions and networks*. Much of the urban growth worldwide is on the fringes of large cities or in satellite towns. Similarly the risk associated with urbanisation includes that found in 'long and thin' networks of critical infrastructure, sometimes generating risk for populations in distant places. Studying megacities on the coast has tended to focus on the urban core, or at times on fringe low-income settlements, there is less work on interconnected and extensive critical infrastructure networks.

What might some of the most important areas of future work be?

Different scientific paradigms are being applied to research on social and environmental systems on the coast. Mental models of knowledge generation include positivistic observation and description (e.g., for snapshots of hazard and vulnerability), systems viewpoints that can help reveal and track emergent properties in ecological, physical, social and psychological systems and their combinations, and models that focus on the communicative element of learning as a co-produced social process. These provide a rich body of approaches to examine and assess. Multiple agendas also meet at the coast: global systems science, sectoral research and case study based expertise are all evident in the work presented in this report. Comprehensive reviewing of these knowledges could usefully start from surveying individual strands of research and then noting examples of actual or potential interaction. While there already exists a considerable amount of multi-disciplinary work in this field it will be important to examine just how far existing approaches can provide bridges for integrated social and biophysical analysis and modelling.

At this moment in the development of a canon of work on megacities and the coast two agendas stand out for maximising the impact of science and the communication of experience.

First, to systematise knowledge arising from the description and modelling of human and environmental (including ecological) systems status in coastal megacities and urban regions, and that make projections or hypotheses about possible futures. Work could usefully review methods as well as findings. For example, it will be useful to examine the balance between hazard and vulnerability led assessments and the extent to which multi-hazard approaches have been developed in the context of and applied to coastal megacities. There is a strong demand for the incorporation of scenarios of urban vulnerability patterns and the development of new methods to model human habitat transformations, and for approaches that can compare the impacts on risk of early warning and risk awareness compared to re-designing the land-use of cities or investing in new engineered solutions to risk management. A systematic review could add value to these debates and push policy and research forward.

Second, to bring together the distributed knowledge on policy experience and informal practices that aim either explicitly or implicitly to adjust (adapt to or mitigate risk). Much of this knowledge is likely to exist at present in the grey literature – or not to be formally recorded at all in the case of multiple individual and local collective adjustments. Bringing peer review scientific and grey literature together is ambitious but is important in contributing to the

dissemination of innovations and strengthening cross-city learning. Recording and analysing evidence on the advantages and disadvantages of different organisational and institutional forms for delivering resilience, as well as the contributions of specific projects for meeting defined risk challenges would be very helpful.

Both agendas could usefully include a focus on the mechanisms through which local actors at risk, city authorities, the private sector and external actors interact and influence the framing of risk and its management. This can extend to an assessment of strategies deployed by leaders to affect change in institutions framing adaptation or mitigation choices and also of research methodologies that engage with the decision-making and policy process recognising that knowledge is co-produced.

The value of any coordinated research agenda or review process is to a great extent determined by its impact on policy and practice. Indeed, science is often most impactful when it is framed and communicated in the language of targeted communities of practice – e.g., finance, health care or environmental management. While any review process may not be able to re-calibrate findings in this way it should be mindful of presenting work that can illustrate such strategic sensitivity. Applying the principles of knowledge co-production, the involvement of urban actors in collecting, reviewing and presenting material for review would be an advantage.

Ways Forward

The preceding discussion and supporting papers go some way to illustrate the diverse range of scientific approaches being applied to the challenge of megacities and urban regions on the coast. Not only are different disciplines engaged but the depth of engagement with the unique challenges of cities on the coast, as opposed to generic concerns of urbanisation or of coastal dynamics are also varied. Understanding those moments where phenomena specific to the urban coast arise can only be possible when building on the depth of knowledge grounded in more generic disciplines. This tension between the specific and generic is especially apparent for the review in hand where there are no dedicated journals, research centres and few individual champions – yet a large and rapidly growing body of scientific evidence and a pressing need for this to be synthesised and made accessible.

In response, two specific products are proposed:

- In the near term: existing support will be used to deliver a systematic review of the literature supported by a small group of coordinating editors representing interested disciplines and geographical regions.

We propose a review that should cover:

- i. The scale, pace and geography of urban systems on the coast, their networked and distributed as well as internally heterogeneous character.
- ii. The ways in which urbanization interferes with environmental processes on the coast, how this is being managed, the effectiveness and any trade-offs in management decisions and why certain management practices are preferred including feedback onto

human systems. This section can be structured by system type, ie: atmospheric, ecological, hydrological, soil, geomorphological, etc.

- iii. The risks and opportunities posed by a coastal location to urban form and function, risk management and its effectiveness for short-term risk reduction and longer-term development goals. To include a review of the scientific methodologies used to identify and communicate risk and plan for the future.
- Additional support will be sought to build a network of city level correspondents through which to track the progress of governance for adaptation, mitigation and resilience and so provide a resource for research, and simultaneously help build a community of practice, especially amongst young scholars to enhance the visibility of work on the urban coast. Collaboration with existing networks such as START, IDRC, ICLEI, IRDR, UGEC and Rockefeller and global institutions with networked membership such as the World Bank and UN-HABITAT and UN-ISDR will be important.

This will require the development of a common template for case study submission, and a process for validating the quality of submitted case studies and an open access web-based system for data management.

The challenges facing coastal, urban sustainability are considerable and made more worrying by the speed of climate change. But cities have always been places of innovation, where elements (social and ecological) come together in new ways. Cities are certainly nodes of transformation with coastal cities perhaps most dynamic and multifaceted of all. The question is perhaps not 'will coastal cities adapt?', but who will win and lose as adaptation unfolds. Structured scientific engagement has a key role to play through bringing together the evidence base, and opening opportunities for critical reflection amongst the full range of stakeholders.

Land-Ocean Interactions in the Coastal Zone (LOICZ)

Core project of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP)

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