Sustaining coastal urban ecosystems

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The 2008 Atlantic hurricane season once again highlighted the challenges awaiting low-lying population centres close to the ocean. In the face of global sea-level rise, unconventional thinking is required to make urban coasts more resilient.

After a brief lull along the shores of the United States following the devastating hurricanes of 2004 and 2005, activity was back in full swing in 2008. Hurricane Ike, the most damaging storm of the past Atlantic hurricane season, affected the full length of Cuba before reaching the US Gulf Coast on 13 September at Galveston, Texas. Just like Hurricane Katrina in 2005, Ike was another near miss: both storms experienced a subtle eastward jog within the last few hours before landfall (Fig. 1). This last-minute sway steered the feared northeastern quadrant — the location of the most powerful shoreward winds and storm surge — just east of the metropolitan centre that had been in the cross-hairs (Houston, Texas, and New Orleans, Louisiana, respectively). Of course, a grim situation unfolded following Hurricane Katrina nevertheless, including the flooding of 80% of New Orleans and the loss of nearly 2,000 lives. This was primarily the result of a broken coastal-defence system[1], although a combination of other factors contributed to the devastation[2].

The vigorous debate of the past few years about the possible impact of global warming on the frequency and intensity of destructive tropical cyclones[3] seems unlikely to be settled soon. Although progress on this critical problem deserves the highest priority, we argue that this discussion is in some respects beside the point. Accelerating global sea-level rise, a subject on which there is remarkable consensus, will exacerbate vulnerability even if its precise magnitude remains uncertain[4]. In the case of the US Gulf Coast, sea level over the past century has risen about four times faster than in the preceding millennium[5]. Given these swiftly changing boundary conditions, even an unchanged tropical cyclone climate will render the coastal zone more vulnerable.

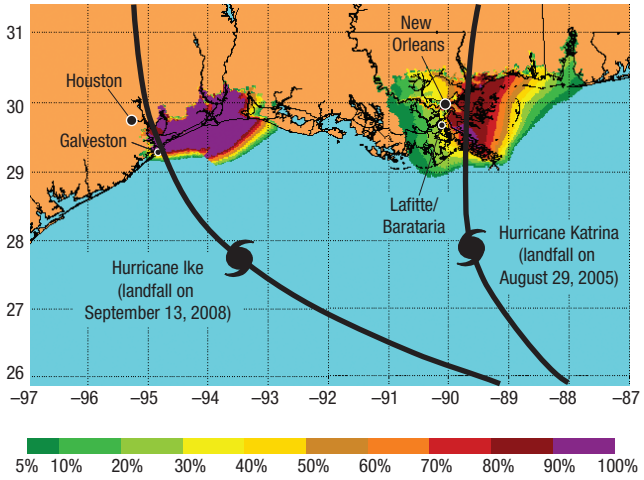

Figure 1 The impact of hurricanes Ike (west) and Katrina (east). The map shows the storm tracks as well as the storm surges predicted with the SLOSH model within hours before landfall (data from the National Weather Service[19]). Indicated are the probabilities of surge heights >3 m; the spatial pattern of these predictions corresponds well to the observed storm surge. Note that the storm tracks and highest surge are located just east of the main population centre in both cases.

Densely populated coastal areas therefore need particular attention, now and in the future. Preserving protective shorelines and wetlands wherever feasible, limiting the growth of urban centres on low-elevation coasts, concentrating the inhabitants of seaside cities in the least-threatened areas and rebuilding destroyed housing in a more resilient fashion could all contribute to enhanced safety and well-being at the oceans' shores.

STARVING WETLANDS

In coastal Louisiana, storm surges associated with hurricanes seem to have been worsening. For example, the Lafitte/Barataria fishing communities, located some 30 km south of New Orleans and 50 km north of the battered Louisiana shoreline (Fig. 1), experienced the highest level of flooding in memory during Hurricane Ike. However, Ike was considerably weaker than its 2005 predecessors (Katrina and Rita) and its eye didn't come within 350 km (the eye of Hurricane Rita, one of the most powerful hurricanes on record in the Gulf of Mexico, passed more closely at a distance of about 300 km). The rapidly deteriorating coastal wetlands in this region, not least by virtue of the pummelling in 2005, could plausibly have left the area more flood-prone: it is often

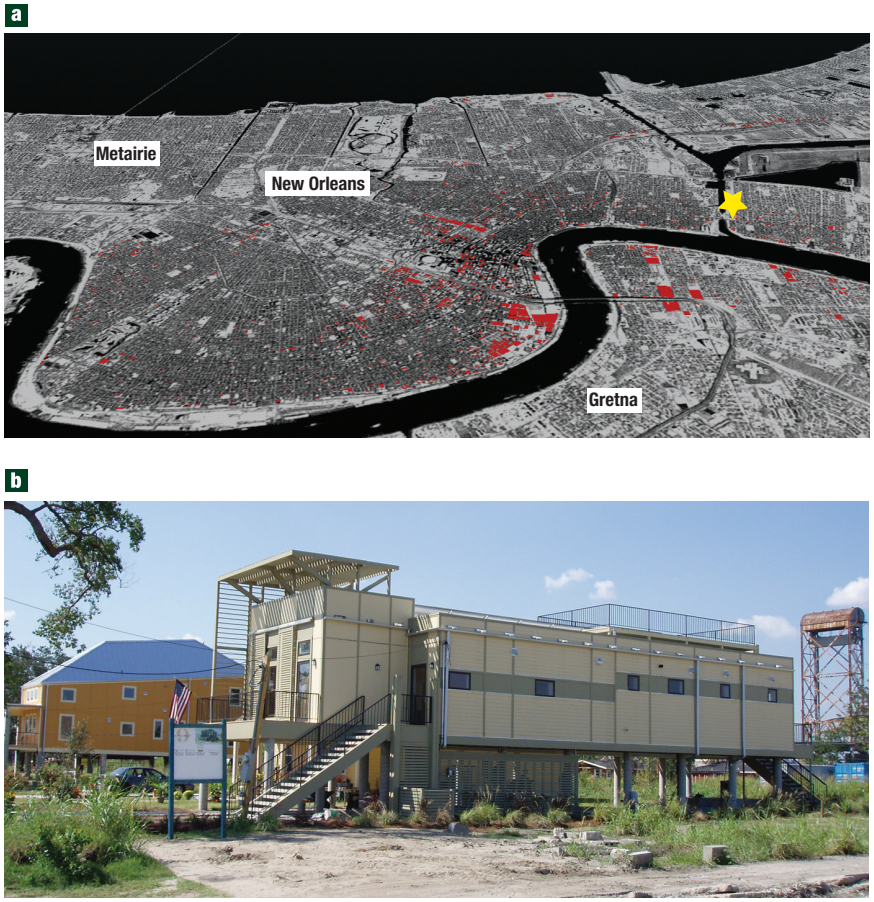

Figure 2 Rebuilding New Orleans. **a**, Significant portions of the city above sea level are currently undeveloped (indicated in red). Image courtesy of R. Campanella. **b**, An example of sustainable rebuilding in the Lower Ninth Ward (yellow star in panel **a**) within the framework of the non-profit 'Make it Right' project[20] spearheaded by Brad Pitt.

claimed that storm surges can be partly mitigated by healthy coastal wetlands[6], although better documentation by field measurements is needed.

The catastrophic loss of coastal wetlands in Louisiana, often estimated at one football field every 30–45 minutes, has been recognized since at least the 1970s (ref. 7). Although a variety of factors contribute[8], the fundamental culprit is the isolation of the delta plain from sediment delivery owing to the embankment of the Mississippi River. Louisiana's acute wetland loss problem was brought to the attention of the US Congress in the late 1990s by means of the 'Coast 2050' plan[9], which proposed a variety of coastal restoration measures. But even with the recent financial commitments of the Louisiana Coastal Protection and Restoration Authority, projects so far have been limited to funding levels that constitute only a minuscule fraction of the price tag of Hurricane Katrina's damage[10].

POLITICS

In the chaotic aftermath of Hurricane Katrina, Dennis Hastert, then Speaker of the US House of Representatives, raised the unthinkable question of whether New Orleans should be rebuilt. Despite the pessimistic sea-level scenarios projected for the coming century, it seems doubtful that abandoning large coastal cities will become a consensus policy anywhere in the world. But at least new urban settlements in vulnerable areas, whether coastal or elsewhere, should be avoided at all cost, particularly in nations where this is more economically feasible. Urban sprawl should be banned in previously flooded areas, such as the floodplains of the Mississippi and Missouri Rivers near St Louis, Missouri, which were inundated during the 1993 flood but have since been developed[11].

Regardless of policy-making opportunities at the local to regional scale, it must be borne in mind that such efforts are only meaningful if the foremost priority is given to combating global warming and accelerated sea-level rise. Casting this in International Panel on Climate Change (IPCC) terminology[12], we argue that in the case of the New Orleans metropolitan area (and probably many comparable coastal urban centres) 'on-site' adaptation is pointless without mitigation. Although this may not be news to scientists and planners, it is all too often an afterthought in the public debate (as reflected by its subordinate role in the recent US presidential campaigns), or it is simply ignored altogether.

NATURAL LABORATORY

The rapidly growing population centres in low-lying coastal settings worldwide (notably in Asia) will face formidable challenges due to sea-level rise in the next century. However, the timing of the onset of adverse impacts will vary, depending on site-specific conditions such as topography, local sea-level scenarios, and the probability of major storm events. The capacity of these urban areas to generate goods and services (including ecosystem services) may increasingly be compromised. Thus, a deeper understanding of the resilience of such urban ecosystems is critical[13].

Within this context, New Orleans can be viewed as a canary in the global warming coal mine. Regardless of whether this particular city should be rebuilt (although it is difficult to argue with its vital economic and cultural role within the United States), New Orleans and its surroundings offer an unprecedented opportunity: a concerted effort to restore and transform a coastal urban centre whose functioning is inextricably tied to its surrounding natural ecosystem can only lead to new knowledge and understanding that will prove critical once comparable conditions confront Shanghai, Tokyo and New York City. Put differently, New Orleans provides an exceptional urban natural laboratory where the impact of global warming can be studied today.

SUSTAINABLE (RE)BUILDING

Restoring New Orleans to its original form is not sustainable[14]. Sustainable development such as that adopted by the IPCC[15] is a hallmark of numerous visions on how and where residents of New Orleans should repopulate the city[14,16]. These studies stress the need to embrace natural processes, account for future flooding and offer viable opportunities to concentrate the population in the comparatively safest areas.

The necessity to concentrate urban coastal populations will only increase in a future of rapidly increasing energy and transportation costs. Furthermore, in any urban centre that relies on an expensive engineered coastal-defence system, consolidation maximizes the return (that is, the safety level) on such large public investments. Unfortunately, these needs are at odds with the blight that characterizes many large cities, particularly in the United States. The population density in New Orleans immediately before the exodus caused by Hurricane Katrina was only about 2,500 residents per square km. By comparison, the present-day population density in Amsterdam, The Netherlands, a city in a broadly similar environmental setting, is almost 4,500 residents per square km.

A recent demographic analysis[17] focused on unused parcels of land to quantify the residential carrying capacity of those portions of New Orleans located above sea level (Fig. 2a). Using the 1960 mean citywide population density, New Orleans could accommodate more than 300,000 residents above sea level (50% of the city's land area), which by US Census Bureau estimates is approximately the current population of the entire city. More than 3 km^2 of land above sea level (including some of the highest ground in the entire city) is at present largely vacant as the result of a four-decade national trend of suburban sprawl into less densely populated, but, in the case of New Orleans, more flood-prone areas. Thus, ample opportunities exist for sustainable rebuilding.

Unconventional residential and commercial building in flood-prone settings has been advocated before[18]. A striking example is the current rebuilding of a portion of the Lower Ninth Ward in New Orleans (Fig. 2b), the area that was devastated most severely during Hurricane Katrina. New flood- and storm-resistant, energy-efficient, environmentally friendly homes are expected to make it one of the 'greenest' communities in the United States, providing a window of hope into the uncertain future inherent in global change.

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References

1. Seed, R. B. *et al. Investigation of the Performance of the New Orleans Flood Protection Systems in Hurricane Katrina on August 29, 2005*; <http://www.ce.berkeley.edu/~new_orleans/> (2006).
2. Törnqvist, T. E. *Neth. J. Geosc.–Geol. Mijnbouw* **86,** 307–315 (2007).
3. Mooney, C. *Storm World. Hurricanes, Politics, and the Battle over Global Warming* (Harcourt, 2007).
4. Meehl, G. A. *et al.* in *Climate Change 2007. The Physical Science Basis* (eds Solomon, S. *et al.*) 747–845 (Cambridge Univ. Press, 2007).
5. González, J. L. & Törnqvist, T. E. *Eos* **87,** 493–498 (2006).
6. Costanza, R. *et al. Ambio* **37,** 241–248 (2008).
7. Gagliano, S. M., Meyer-Arendt, K. J. & Wicker, K. M. *Gulf Coast Assoc. Geol. Soc. Trans.* **31,** 295–300 (1981).
8. Day, J. W. Jr *et al. Estuaries* **23,** 425–438 (2000).
9. Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority. *Coast 2050: Toward a Sustainable Coastal Louisiana* (Louisiana Department of Natural Resources, Baton Rouge, 1998).
10. Day, J. W. Jr *et al. Science* **315,** 1679–1684 (2007).
11. Pinter, N. *Science* **308,** 207–208 (2005).
12. Nicholls, R. J. *et al.* in *Climate Change 2007. Impacts, Adaptation and Vulnerability* (eds Parry, M. L., Canziani, O. F., Palutikof, J. P., Van der Linden, P. J. & Hanson, C. E.) 315–356 (Cambridge Univ. Press, 2007).
13. Elmqvist, T., Alfsen, C. & Colding, J. in *Encyclopedia of Ecology* (eds Jørgensen, S. E. & Fath, B.) 3665–3672 (Elsevier, 2008).
14. Costanza, R., Mitsch, W. J. & Day, J. W. Jr *Front. Ecol. Environ.* **4,** 465–472 (2006).
15. Halsnæs, K. *et al.* in *Climate Change 2007. Mitigation of Climate Change* (eds Metz, B., Davidson, O. R., Bosch, P. R., Dave, R. & Meyer, L. A.) 117–167 (Cambridge Univ. Press, 2007).
16. Birch, E. L. & Wachter, S. M. (eds) *Rebuilding Urban Places after Disaster. Lessons from Hurricane Katrina* (Univ. Pennsylvania Press, 2006).
17. Campanella, R. *Above-Sea-Level New Orleans* (Tulane/Xavier Center for Bioenvironmental Research, New Orleans, 2007).
18. Kabat, P., Van Vierssen, W., Veraart, J., Vellinga, P. & Aerts, J. *Nature* **438,** 283–284 (2005).
19. http://www.weather.gov/mdl/psurge/archive.php
20. http://www.makeitrightnola.org

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