

## **Out of Harm's Way: Challenges in Reducing Current and Future Coastal Risk Exposure**

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### **1. Introduction: The key risk conundrum at the coast**

Coastal areas are increasingly facing the combined risks of climate changes unfolding over land and the oceans (Wong et al. 2015; Moser et al. 2014). These risks interact with the social-ecological realities of a highly developed, densely populated, ecologically already degraded, and yet economically crucial region (Moser et al. 2012). This confluence of forces creates complex risks and virtually assures that coastal areas will see increasing losses of lives, land, and livelihoods unless significant efforts are undertaken – and fast – to reduce exposure to episodic risks from storms and floods, and chronic, persistent risks from sea-level rise. Path-breaking new science suggesting sea-level rise could rise much faster than previously thought only underscore this point (DeConte and Pollard 2016). To the extent prior investments become stranded assets and the funds invested in protective and adaptive measures are not available for other purposes, the financial means potentially lost at the coast amount to nearly unfathomable losses.

Given these enormous stakes, the large number of people at risk, the many, and frequently competing interests, it is extremely difficult to find even partial solutions, much less comprehensive ones. Moreover, efforts to find any solutions must be made repeatedly – both in places, given the context sensitivity of adaptive solutions along the world's hundreds of thousands of miles of coastline – and in time, because sea level is expected to continue to rise for millennia, even if greenhouse gas emissions were stopped immediately (e.g., Golleger et al. 2015; Strauss et al. 2015). This wicked problem is rooted in the countless land use choices and investments humans have made to locate, work and recreate in one of the Earth's most dynamic environments (Levin et al. 2010; Perry 2014). Deep-seated human values, policy preferences, taxation schemes, and economic forces reinforce the very drivers that maintain these trends. The growing coastal risk exposure thus emerges as the poster child of one of hazard management's greatest risk conundrums, namely: how to reduce current and future exposure to a hazard when past investments and current demographic, socio-economic, political and climatic trends all "conspire" to place more people and more things people value in harm's way.

Resolving this particular conundrum is indeed – as the definition of "conundrum" implies – a confusing and difficult problem with only "wicked" answers. But not solving it may be as risky as the growing coastal risks themselves. In Sophocles' infamous riddle of the Sphinx, Oedipus must resolve a perplexing conundrum or else risk being eaten by the Sphinx!

In this chapter, we focus on the U.S. and lay out some of the drivers behind this risk conundrum (Section 2), clarify why we cannot avoid dealing with it (Section 3), and open up the discussion of how to intervene in this complex system in order to avoid catastrophic losses of

lives and resources in the future (Section 4). While it is comparatively easy to propose "solutions" on paper, we know that this discussion and even more so the on-the-ground implementation of these ideas are countercultural, politically contested, and extremely challenging because they aim to redistribute power, resources, risks and benefits. We expect them to meet resistance. To us, it seems, only standing by the coming suffering is more difficult than the attempt to address it.

## **2. The deep drivers of the current coastal risk conundrum**

### ***2.1 Getting into harm's way***

Currently, in the U.S., more than 164 million people (about 50% of the population) live in coastal areas and each year, another 1.2 million move to the coast (Moser et al. 2014). In terms of direct exposure to coastal floods, 2.8% of the U.S. population, or more than 8.6 million people, live within areas subject to coastal floods that currently have at least a 1% chance of occurring in any one year (Crowell et al. 2013). Many more (120 million) live in the coastal counties that could be affected by such storms. Strauss et al. (2012) estimated that already, "some 2150 [U.S. coastal] towns and cities have some degree of exposure" to flooding and sea-level rise given their location within 1m of high tide.

With these highly concentrated coastal populations come enormous investments in infrastructure and buildings, along with significant economic activity. For example, more than half of U.S. GDP is generated within the narrow coastal zone (Moser et al. 2014). In 2012 on the Gulf and East coasts of the U.S. alone, the "total value of insurable property in ZIP Codes potentially impacted by storm surge [was] \$17 trillion" (Doggett 2015). Of this total, only about 62% are actually insured. The total potential economic losses from such flood disasters tend to be multiple times those of insured losses and typically are born by the government, i.e., by tax payers.

This cursory review of basic population and economic figures suggests that coastal areas are magnets: throughout history, they have drawn people and economic activity into some of the world's most beautiful and also most dangerous areas. Why?

"Coastal zones have always attracted humans," according to Neumann et al. (2015: 2), "because of their rich resources, particularly their supply of subsistence resources; for logistical reasons, as they offer access points to marine trade and transport; for recreational or cultural activities; or simply because of their special sense of place at the interface between land and sea." Others add to this list of reasons a relatively mild climate (at least in the most populated low-to-mid-latitudes), the beauty of coastal regions, and vibrant urban centers with economies that promise employment and trendy cultures (Nicholls et al. 2011; Brereton et al. 2008; Martínez et al. 2007).

The desirability of living along the shore is amply reinforced by a number of economic incentives and related drivers. Bagstad et al. (2007) reviewed various incentives and

disincentives to develop the coast, protect natural features that could provide a certain degree of hazard protection, and otherwise mitigate coastal risks in the U.S., and found that there is no single set of drivers behind the continuing migration to the coast. They did find, however, that synergistically, taxes, subsidies, and flood insurance availability combine to serve as powerful drivers of continued coastal development. Contradictory incentives emanate from different levels of government, while underlying economic drivers push on (see also Salvesen 2005; The Heinz Center 2000).

These economic and policy drivers are compounded by a lengthy list of human impulses and inclinations to avoid dealing with hazards, including relatively low importance given to vulnerability versus other concerns, risk perceptions that attenuate concerns when hazards are slow-onset and relatively familiar, limited resources and competing priorities, weak planning systems, a shortage of political will, short time and decision horizons, emphasis on private property rights over public property and individualism, and a refusal to bear the upfront costs of hazard mitigation (Beatley 2009). In the U.S., this combination of drivers, impulses, and inclinations set the stage for development of high-risk coastal areas without adequate regard for current or future risks.

Not surprisingly, the world of real estate development and land use planning expects continued investment in coastal areas (Titus et al. 2009, JLL Staff Reporter 2015). In fact, the value of shoreline property is constantly increasing, and increasing more than in other locations (Your Mortgage 2016; Knight 2014). In sum, investment in coastal areas is unabated or even accelerating (Doggett 2015).

## ***2.2 Local politics and power struggles in decision making***

Global economic trends and fiscal incentives alone, however, do not explain entirely why reducing risk exposure along the coast is so difficult. Local efforts to adapt to emerging threats are influenced in important ways by local institutional, budgetary, and community factors which interact with those supra-local drivers of coastal development. They can create inertia in dealing with new threats and in dealing with existing threats in new ways.

To start, municipalities are commonly driven to promote economic development and the accumulation of private capital due to the tax income and employment they generate, and the influx of money from outside the community they ensure. Local governments have little incentive to get in the way or devote sufficient attention to equality or preparedness (Sassen 1991). Moreover, the inbuilt inertia of institutions slows down or impedes efforts to innovate and reduce risks, especially when those who are “winners” in existing patterns of development (e.g., developers, elected officials, home or business owners, local government departments, influential outsiders) may lose benefits, opportunities or budgets.

Such entrenched economic and political power may be in the hands of a few. Power may be held by individuals or families with deep roots in a community, exerting decisive influence over planning and decisions. Repeated and rising costs to the municipality and local residents in Dauphin Island, Alabama, for example, from recurring storm related cleanup and restoration of

infrastructure, are creating a divide among those who view continued occupation of vulnerable homes as unsustainable and those who own those homes or earn income from tourist rentals (Tuler and Webler 2013). So far, the stalemate and absence of another disaster have allowed the community to avoid having to make hard choices about long-term solutions (AP 2014). Resistance to retreat by residents limit options of authorities in many locations (e.g., Douglas et al. 2012; Agyeman et al. 2009). Even initial efforts to simply better understand distributional impacts can exacerbate conflict and make planning harder (Walker 2010).

Competing missions can further complicate matters. For example, efforts to improve water quality and reduce threats of coastal erosion in Boston Harbor and Cape Cod Bay (Massachusetts) through restoring shellfish beds have faced regulatory obstacles from state agencies responsible for public health due threats such as *e. coli* and *vibrio* (Frankić et al. 2012). Budget constraints further exacerbate local conflicts over priorities. Economic development and employment stability, pollution and health issues, population growth and infrastructure all need attention in addition to adaptation.

### ***2.3 Too big to fail***

When disasters like Hurricane Katrina occur, they never remain just coastal. This is due to the interconnectivity of demographic, economic, infrastructure, institutional and social linkages that tie coastal populations to the hinterland, and coastal regions to each other across oceans (Moser and Finzi Hart 2015). A storm disrupting critical coastal oil refineries, can raise an entire nation's gas prices; hurricane-related wind or flood damage can make the lights go out across a region; far-away floods can disrupt economic production in countries around the world (Dismukes and Narra 2016; Moser and Finzi Hart 2015). This makes the risk conundrum of coastal exposure far more than just a "local problem", but can pose a systemic risk, whereby tipping points get crossed that transmit difficult-to-control impacts to other systems (Goldin and Mariathan 2014). Given their importance to regional, national and global economies, coastal cities are thus in many ways "too big to fail," suggesting both an opportunity and an obligation to address the coastal risk conundrum collectively and at multiple scales.

The "too big to fail" and closely-related "too central to fail" logics took center stage during the response to the 2007-8 financial crisis. A brief period of hindsight and motivated research has not fully settled the controversy over how to assess the amount of systemic risk emanating from an institution due to its size and position within a network (Leopfe et al. 2013). Yet many investments in coastal regions around the world call forth the same logics and debates. Multiple networks and systems of interdependency and social connection have within them central nodes with exceptional potential capacity to transmit stress, disruption, and losses outside their boundaries (Allianz 2014; Moser and Finzi Hart 2015).

Seaports, situated in areas at high risk to sea-level rise and severe storms, serve as a prime example given their importance to national economies, import of goods, and international trade (Becker et al. 2015). The world's largest cities are tied to many of these ports, which are connected to trade and inland transportation systems (Moser et al. 2014).

Concerns about energy, food, transportation, and national security intersect in these critical nodes. According to Moser et al. (2014), "more than \$1.9 trillion in imports came through U.S. ports in 2010, with commercial ports directly supporting more than 13 million jobs and providing 90% of consumer goods" (p. 589). In some cases, these points of entry are disproportionately important for particular sectors. For example, in 2011, the New Orleans Port Region handled 33% of water-borne agricultural import and export trade; the second and third largest ports are on the West Coast (Los Angeles, CA and Kalama, WA), each handled only 6% and 5%, respectively (USDA 2013). As the U.S. Global Change Research Program Report observed of the Gulf Coast, "The importance of these marine facilities and waterways to the study area, and to the Nation as a whole, is difficult to overstate. ... While some of these functions could be considered 'replaceable' by facilities and waterways elsewhere, many of them – by virtue of geography, connections to particular industries and markets, historic investments, or other factors – represent unique and largely irreplaceable assets" (USGCRP 2008: 2-2).

The Gulf Region also provides a good example of the pressures on maintaining these systems in place without thinking much about the climate change to come. Hurricane Katrina resulted in \$50 million in direct damages to the Port of Gulfport, Alabama. However, indirect impacts, such as difficulty obtaining materials, loss of business continuity, unemployment, and increasing prices, slowed down its recovery. In the process of rebuilding, the project environmental plan was revised to include elevating the port by 10 feet by 2017 to increase the port's resilience (Becker et al. 2015). However, by 2012 the responsible State Port Authority decided to decrease the elevation component in order to bring the port back on-line faster (Becker et al. 2015; see also <http://www.portofthefuture.com/>).

Given the crucial importance of port cities in the U.S. and worldwide, "failing to adapt is not a viable option in coastal cities" (Hallegatte et al. 2013: 805). This echoes the *Global Risk Reports* of the World Economic Forum, which have listed failure to adapt as one of the most significant risks to the global economy (e.g., WEF 2016).

### **3. The inevitability of retreat: The risk conundrums soon to come**

#### ***3.1 Society and sea level on a collision course***

The trends and interdependent factors depicted in the previous section alone guarantee that growing numbers of people and structures will be at risk from coastal storms, erosion, and flooding. But societal trends tell only half the story. Climate changes will magnify coastal risks. Cognizant of the dynamics of Earth systems, we know that the already observed sea-level rise will not only continue but accelerate (Church et al. 2013). How much, how fast and how long depends on a number of unknowns and inadequately understood dynamics, including societal efforts in mitigating climate change and Earth system feedbacks (e.g., carbon cycle, ice melt processes, ocean current changes and the net effect of land rebound and sinking in any one location) (DeConto and Pollard 2016; Hansen et al. 2016; Holland and Holland 2015).

Absent greater scientific capability to accurately predict future sea-level rise, scientists offer alternative scenarios to inform planning and policy-making. Haer et al. (2013), for example, considered relative sea-level rise scenarios between 0.2 and 2m above present levels and found that an area the size of 55 to 162 Los Angeles could be inundated, putting between 1.8 to 7.4 million people at risk. A more recent study, accounting for population growth, estimated that 4.2-13.1 million people could be at risk from 0.9-1.8m of sea-level rise by 2100 (Hauer et al. 2016).

### ***3.2 Holding back the sea indefinitely?***

Of course, these projections assume no adaptation, but whether or not these at-risk populations can successfully adapt in place (i.e. protect against sea-level rise and related flood and erosion risks, saltwater inundation, and higher storm surges) and not become displaced, depends on many factors. Among them are the rate of sea-level rise (i.e., the time available to plan for and implement protective responses), changes in coastal storm regimes, societal readiness to acknowledge the problem, and a willingness to pay (and pay again and again) for the necessary protective measures. Such factors are exacerbated by the challenges of accepting the ecological, visual, and other implications of protecting against the rising sea, and the institutional, political and technical capability to mount the necessary adaptive response and maintain it indefinitely.

Many developed, wealthier coastal regions currently opt for costly protection against (still relatively small amounts of) sea-level rise (e.g., EC 2009; Gittman et al. 2015). While highly cost-effective compared to no protection, actual adaptation expenditures tend to be on the upper end of theoretical adaptation cost estimates, and currently do not include the costs of protection against saltwater intrusion or ecosystem service loss, as such numbers are not yet available (EC 2009). Other studies project that the expected expenditures for protection and accommodation in place will increase significantly over the 21<sup>st</sup> century (e.g., Anthoff et al. 2010, Hinkel et al. 2014). Given the high cost of adaptation, these authors conclude that defending against the sea is the most likely response in wealthier regions.

However, poorer, smaller communities – even in highly developed nations – are likely to find this adaptive challenge beyond their capacity. Early cases of coastal abandonment (e.g., Bronen and Chapin 2013; Maldonado et al. 2013), and a number of anticipatory studies (e.g., Martinich et al. 2012; Titus et al. 2009) suggest differential capability to finance protective measures or planned relocation.

One reason is the economic feasibility of protection in perpetuity. In fact, the bold assumptions of high cost-effectiveness and, therefore, adaptation affordability and sustainability are born out (so far) in only the wealthiest metropolitan areas (e.g., New York and Miami). The stark reality on the ground is rather different: many coastal communities, even in generally wealthy coastal regions of the U.S. (such as the San Francisco Bay Area), already find themselves hard-pressed to generate the necessary staff capacity, financial means, and political will to deal with even just the early adaptation planning challenges (e.g., Bierbaum et al. 2012; Moser and Ekstrom 2012). Maybe societal priority setting will change and money will become

available. This change, however, would require radical shifts in risk perceptions and understanding, disaster experience, societal expectations of disaster and recovery aid, institutionalized incentives for coastal development and for adaptation, and the financing options available.

The second reason for skepticism about the viability of holding back the sea forever relates to the technical feasibility and knock-on effects of shoreline protection against a relentlessly rising ocean. It is well understood that hard or soft shoreline protection (seawalls, revetments, groins, beach replenishment, ground elevation etc.) in high-energy coastal environments is technically difficult and expensive at best, but often not viable at higher rates of sea-level rise. Even where it is attempted, beaches, coastal ecosystems, viewsheds, and other public amenities are being lost (Gittman et al. 2015; Beatley 2009). One might argue that people can get used to manufactured shorelines and that the loss of coastal ecosystems may be a socially acceptable trade-off. But that assumption may rest on a narrow, privileged, and urban perspective. Many species depend exclusively on coastal ecosystems for survival. Meanwhile coastal tourism and recreation (in turn dependent on healthy beaches and wetlands) make up one of the largest sector of the tourism industry, which is not only the fastest growing sector of the service industry but, in many regions, also the single largest economic driver (e.g., Moser et al. 2014). Coastal fisheries, also dependent on viable coastal ecosystems, may not constitute a large share of GDP in the U.S. (ca. \$7.3 billion in 2013), but they can be regionally important and the source of livelihood for some 62,000 people (NOAA 2016). Thus, to merely compare the cost of shoreline protection against the potential losses of unprotected development, misses the countless ecological, economic, and eventually social run-on effects of sacrificing natural aspects of the coast.

A third reason that makes perpetual shoreline protection unlikely is that in order for it to be effective, it would need to be built and maintained in large continuous swaths. And that would require that many different actors at different levels of government, with divergent interests, different authorities, and variable means come together as one to align their efforts in shoring up and maintaining protective structures. To our knowledge, this level of coordination is unprecedented in the history of coastal management in the U.S. or any other nation.

### ***3.3 Injustice for vulnerable populations***

The discussion of direct costs, technological feasibility, undesirable consequences, and improbable levels of coordination masks the distributional justice issues involved in adaptation. As one recent study put it bluntly, "local protection may not be physically possible or economically feasible everywhere. ... Local protection will most likely only be done for areas where valuable assets are at risk and will not cover entire coastlines, including poor areas and ecosystems" (Frieler et al. 2016: 202-203). Considering the differential capability to generate the necessary funds for adaptation puts a finer point on the question of perpetual protection: many less well-off communities – urban or rural, large or small – will find themselves in terrible dilemmas. Adaptation limits, i.e. the point when communities can no longer meet their goals,

will be reached far sooner by some than by others (Dow et al. 2013). If adaptation spending in the world's megacities is any indication, then wealth is a stronger predictor of taking preparedness and protection measures than the size or needs of vulnerable populations (Georgeson et al. 2016). In other words, insufficient attention may be given to those most in need.

One of the more detailed analyses on the potential differences in fiscal capacity for adaptation has been conducted in the U.S. Martinich et al. (2012) assessed the likelihood of different forms of adaptation (protection, accommodation, or abandonment) to occur as a function of U.S. coastal areas' exposure to sea-level rise and the socioeconomic status of coastal communities. They found that as social vulnerability increases, the land area and population protected from sea-level rise through either armoring (protection) or beach nourishment (accommodation) decreases, while the area and population abandoned increases. Gittman et al. (2015) gave weight to this outlook by examining the extent of existing hard shoreline protection in the U.S. (nearly 23,000 miles or 14% of the total). They found that housing density and gross domestic product were among the positively correlated factors, which is consistent with existing benefit/cost formulas used to justify, and thus the ability to afford, major shoreline protection. If these studies highlight the socioeconomic injustices involved in community-level adaptation, similar challenges are well established for the ability of individual households to cope with and recover from disasters. For example, after Hurricane Katrina one study found that, "pre-existing socio-economic conditions were not predictors of flood damage, but they played an important role in the response and recovery phases" (Masozera et al. 2007: 304).

Complicating the discussions about the ability to adapt in place even further, residents of two coastal neighborhoods in Boston reported that they do not see permanent retreat as an option because of their desire to remain near family and friends and the difficulty of obtaining low-priced, affordable housing elsewhere (Douglas et al. 2012). Connection to place, family, friends, work and the economic investment made in one's home are commonly recognized ties that explain why many will not want to leave, despite the risks, and consider relocation only as a matter of last resort (Agyeman et al. 2009). However, there is little evidence that addressing equity issues is a strong priority locally as yet. Existing ways of allocating funding to shoreline protection projects have resulted in nearly insurmountable difficulties for low-income, rural and otherwise disadvantaged regions to find the needed support to either adapt in place or to relocate (Bronen and Chapin 2013; Maldonado et al. 2013). Even in cities with climate change and sustainability plans, while equity is commonly mentioned as a goal or issue to be addressed, it is rarely a prominent theme (Schrock et al. 2015).

### ***3.4 Dealing with human legacies on the coast***

If the more critical perspective on the feasibility of sustained shoreline protection is borne out in practice, particularly in less wealthy communities, determining where to retreat to, how to fund and support relocation, and how to foster absorption of those displaced by sea-level rise through institutional mechanisms, targeted economic policies, and cultural, educational and social



programs will become increasingly pressing. We must also look over our shoulders and ask: what are we leaving behind? Who will remove or clean up the "exposure" that stays behind? While people can walk or drive away, their homes (or their storm-struck remnants), roads and bridges, shopping malls, schools and hospitals, sewage treatment plants, cemeteries, landfills, oil refineries, and power plants cannot.

To our knowledge, no focused discussion has taken place to date as to who is financially, legally or operationally responsible for such actions. The fall-back position, however, seems to be the public purse. (Banking opportunistically on recovery funds after devastating storms like Sandy or on horrific accidents like the BP oil spill to use settlement money for coastal restoration and hope that future sea-level rise is taken into account is to us, at best, a cynical approach to the matter.) No comprehensive national or sub-national policy exists to date to address the management of the legacies we will leave behind when coastal occupation becomes untenable.

In individual cases, some relatively small-scale challenges have been addressed in an ad hoc fashion, for example by relocating the human remains from a cemetery threatened by erosion in Oregon; building protection around an erosion-threatened landfill in Barrow, Alaska; moving an iconic lighthouse inland from the eroding shore in North Carolina; or permitting agencies demanding San Francisco Bay developers demonstrate fiscal capacity to protect or remove a structure if and when sea level threatens it. The U.S. EPA also recently acknowledged that climate change and sea-level rise could undermine the effectiveness and resilience of remedies for Superfund sites (EPA 2016). The question of how to deal with larger problems, however, has been skirted. The Turkey Point nuclear power plant in south Florida is a case in point. In the context of deciding whether or not to expand or remove that power plant from its current location at sea level, ratepayers were unwilling to pay for the removal cost, thus a permit was granted to expand it in place with minimal accommodation of future sea-level rise (described in Moser et al. 2014).

## **4. Proposals for overcoming the coastal risk conundrum**

### ***4.1 Stop wasting precious time***

Growing coastal risk exposure qualifies as a wicked problem in both the problem definition and possible solutions – always partial and temporary, inevitably contested, and creating difficult-to-predict and hard-to-manage consequences. Below we offer some suggestions as starting points for necessary discussions, using the dynamics discussed above as possible entry points into tackling this conundrum. Importantly, they rest on the following premises:

- at present, the amount of money allocated to coastal adaptation is vastly insufficient, even in wealthy nations;
- the money allocated to adaptation does not address deep-seated social inequities; and
- most coastal managers do not yet fully acknowledge or grasp the magnitude of the challenge and the implications of either protecting in place or relocating significant

portions of coastal communities and dealing with the human legacies that will be left behind.

A sufficiently frank, systemic and forward-looking public conversation about the future of our coasts has yet to be initiated. Existing institutional mechanisms for coastal planning and management – once built for stability – will prove inadequate for dealing with a far more dynamic coastal environment and for a future faced with a perpetually encroaching sea (Birkmann et al. 2015; Glavovic et al. 2015). "Mainstreaming" more adaptive features into them, while expedient and beneficial for the early adaptation challenges, are insufficient to address the systemic risk conundrum at hand.

Urban planners have identified financial, institutional and staff constraints as the most important barriers to adaptation even at this relatively early stage (e.g., Ekstrom and Moser 2014). Faced with these challenges, there is little appetite to prepare for the far bigger challenges ahead. Yet, cognizant of the effort and time required to garner sufficient public awareness and engagement, initiate the necessary policy processes, commence institutional changes, and generate adequate financial means to successfully adapt to climate change, we see the window of opportunity closing in which we can shape the future rather than merely react to it. If it is beyond the capacity of individual communities to address the risk conundrum delineated here, we believe scientific and policy-making elites must begin to assess realistic options for coastal communities now. This could be done through a series of studies by the U.S. National Research Council, or a specially-appointed, high-level Commission for the Future of the Coast (akin to the U.S. Commission on Ocean Policy) and should be launched immediately while sea level still climbs relatively slowly – the luxury end of the projected exponential curves – because the time to adapt gets shorter and shorter as time goes on.

#### ***4.2 Buy more time***

A second point of intervention is to buy more time for the necessary public deliberations, policy development, and implementation of feasible adaptation strategies. This will involve several types of action. First, the federal Coastal Zone Management Act (and related programmatic funding opportunities), as well as hazard mitigation and other programs should be amended to encourage or even mandate more forward-thinking hazard mitigation efforts. This would include elevation of buildings and critical building contents, integration of nature-based infrastructure, coastal ecosystem restoration, and other community preparedness measures that allow residents and businesses to “live with rising tides” (Douglas et al. 2013). Such measures would increase the near-term hazard resilience and be beneficial in its own right but also buy time.

That time should be used wisely. For example, a number of studies are now available to delineate which areas of the coast are most likely to be protected, where human settlements are most likely to persist for some time with adequate accommodation of the growing sea-level rise risks, and which – in time – may need to be abandoned (e.g., Titus et al. 2009; Martinich et al. 2012, Strauss et al. 2012; Gittman et al. 2015). The State of Louisiana took just such an approach in its *Master Plan for a Sustainable Coast* (State of Louisiana 2012). Research to develop such a

delineation would constitute the first step in characterizing the adaptive response space (or resilience space) available to coastal communities; identifying adaptation pathways; and pinpointing promising, if difficult, approaches for each type of land (Textbox 1). More importantly, it would help focus policy attention on areas requiring priority attention.

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Undoubtedly, efforts to characterize and assess resilience spaces will generate difficult conversations at all levels of government and social organization. Expecting that, a parallel concerted effort is needed in growing the deliberative engagement capacity to enable these difficult conversations. Curtin (2014) calls for "resilience design", the development of essential processes to support the management of wicked problems, arguing that "the more complex or 'wicked' a problem ..., the more informal means ... are needed to address it" (p. 4). This capacity for effective, meaningful engagement and deliberation is currently not well developed and must be built (Moser and Pike 2015; Tuler et al. 2015).

#### ***4.3 Don't get into harm's way***

A number of proposals have been made to reduce the incentives to develop hazardous coastal areas, ranging from reforms of the National Flood Insurance Program, to the expansion of the Coastal Barriers Resources Act, to changes in disaster cost accounting standards, removal of subsidies and many other ideas (e.g., The Heinz Center 2000a,b; Bagstad et al., 2007; Gaddis et al. 2007; Duxbury and Dickinson 2007; Beatley 2009; Titus et al. 2009; Kousky and Kunreuther 2015). These incentives must be reduced at all levels from which they originate. Coordination and consultation will be critical to find the most effective approaches. Because other development drivers, namely economic and demographic factors, are supra-local, piecemeal withdrawal of any one set of subsidies (in the form of incentives for certain economic extractive activities, tax breaks, or insurance) will not suffice. Instead, anticipating that development pressures will continue, that development must be *redirected* toward safer places through the coordinated realignment and redirection of subsidies, zoning, local taxation schemes, and related policy measures toward more desirable places. This must be done in a transparent, coordinated and predictable manner over a clearly defined timeframe (e.g., 10 years, a common planning horizon), combined with effective, repeated communication with relevant stakeholders. The determination of "safer places," of course, will be highly political. Strong leadership (including from within the development, financing, insurance and government sectors), strong and inclusive public engagement, and a strong scientific basis (as described in the previous section) are thus critical prerequisites.

In addition, any public financing, federally insured private financing, post-disaster reconstruction or new infrastructure investment must stipulate planning time horizon extended to at least 2100, beyond the length of a typical mortgage cycle. Local and state regulation should mandate risk disclosure from the start of any real estate transactions and require proof of some

form of property-linked adaptation fund for all new and rebuilt structures, so that private financing will be available when it is needed.

#### ***4.4 Get out of harm's way***

Additional measures are needed to address the existing exposure. Research along the lines described in Textbox 1 would help delineate priorities for relocation from the coast, while other areas invest in accommodation or protection. Importantly, neither staying in place, nor moving back from the shoreline will be low-cost, and government funding – from any level – will not suffice to finance the necessary adaptation steps. Instead, a crucial need is to engage the private sector (development, real estate, banking, insurance etc.) in developing innovative financing instruments and in making safe(r) coastal redevelopment profitable. In fact, there is a growing interest in both research and policy communities in exploring creative adaptation financing, while others are beginning to make "the business case" for investing in resilience (McCormick and Marshall 2016). In short, far greater resources could be mobilized to enable adaptation by changing the development subsidies and incentive structures and redirecting them toward safer locations, while involving the private sector in creative financing and generating profit from building resilience.

Several additional measures must be taken to "get out of harm's way." This is in many ways the far more difficult task, given the trillions of dollars of existing investment, the challenges in removing large infrastructure, finding the most appropriate timing, and changing human expectations. Historically, it was relatively safe to assume a stable coast, make plans for the future, and assume reliable government services and support for living along the coast. The respective responsibilities of individuals and the government were clear; returns on investment assured. To start changing these expectations, a symbolic and politically impactful move would be to include disaster-related expenditures as a standard component in annual federal and state budgets (currently such costs are not routinely "planned for" even though they are routinely incurred). Moreover, a clear plan must be developed and funded for the withdrawal – over time – of publically financed and maintained government services, such as transportation, water treatment, information, and other infrastructure. At the same time, governments will need to clarify which types of shorefront activities will continue to be permissible (e.g., recreational uses, limited-size removable structures, beach clean-up and grading, active conservation of coastal ecosystems). Government-financed buy-outs, and public-private co-financed and co-managed coastal restoration and maintenance of restored areas as natural buffers in perpetuity would be a necessary complement.

A key focus in reducing coastal exposure must be on socioeconomically disadvantaged communities. For the many reasons identified above, it is time to prepare for situations where and when our technological, financial, institutional, and socio-political capacities are no longer sufficient to achieve adequate protection or accommodation. The first cases of that failure – such as in Alaska or Louisiana – demonstrate that at a national level even a rich country like the U.S. is not prepared to address the challenge in a coordinated, effective way (Bronen & Chapin 2013;

Maldonado et al. 2013). We thus believe it is important to break a societal taboo and prepare for many more such cases. By this we do not mean abandoning immediately, prematurely or abruptly, as the sunk and wholesale relocation cost, lack of political acceptance and unfairness would make it prohibitive. But identifying areas likely to be abandoned, establishing realistic timeframes, delineating tolerable, phased adaptation pathways, and beginning to explore and plan for who, when, how and where to relocate with dignity are critical steps that should be begun now (Textbox 1). This exploration will cast light into unanswered questions such as: are the relevant institutions and organizations ready to facilitate the risk governance questions likely to emerge (Dow et al. 2013)? Are legal and regulatory processes clear and in place to facilitate the cessation of services (e.g., transportation infrastructure, sewage, emergency response) (Siders 2013)? Are alternative locations, affordable housing, employment opportunities and social programs in place to meet the needs of affected people (Douglas et al. 2012)? How far does or should the responsibility of government go in assisting communities to relocate to safer ground?

All these efforts must be designed in ways that take account of the lessons learned about human needs and desires to live along the coast, place attachments and cultural meaning and practices, socioeconomic disadvantages and opportunities, fair and democratic processes, and policy windows opening and closing all too quickly in the aftermath of disasters.

#### ***4.5 Remove human legacies***

In addition to reducing exposure, the issue of human legacies of coastal occupation – especially, the challenging case of very large structures and high-risk installations such as toxic or nuclear sites – suggests that it is crucial to begin developing a comprehensive policy, engage in public debate, and develop funding, operational, and institutional oversight mechanisms for deliberate removal. The political will and financial resources needed to do so are enormous, given the very high investments made on the coast historically. Having assumed perpetual human occupation of the coast, there was no perceived need to develop institutional mechanisms or technologies, nor "coastal removal, clean-up, and restoration" funds to manage retreat. Again, small-scale precedents and building blocks are available, including the technical knowledge of how to remove smaller buildings, cleaning up after disasters, restoring once-contaminated industrial sites, building "green" infrastructure and restoring degraded ecosystems. But piecemeal approaches will be inadequate. A comprehensive, transdisciplinary research program on culturally sensitive, ecologically sound, economically fair, and phased coastal removal and restoration is needed (Ruth and Franklin 2014) to inform coastal policy development and a "deconstruction and recycle industry."

#### ***4.6 Change local politics***

Given the importance of local politics in managing risks, and the ways they can impede effective management, attention is also needed on the people involved in them. The "holy grail" will be to align individuals across government, sectors, and divergent interests. Both exogenous and

endogenous forces can help promote this alignment around adaptation and innovation in municipalities facing climate risks (Carmin et al. 2012).

Exogenous forces stem from new policies and regulations enacted at the national or state level, such as those outlined above: changing financial incentives, withdrawal of government services, change of insurance schemes that support building or rebuilding in vulnerable locations, mandates to strengthen hazard mitigation, or buy-out funds. All these can alter development patterns and the local power structures that support them (Bagstad et al. 2007). In fact, as much as policies imposed by higher levels of governance sometimes are criticized and resisted, they also constitute a supra-local authority that can help overcome the kinds of local socio-political dynamics that stymie progress on contested matters (Moser 2000).

Additionally, endogenous factors can change local politics as well. Nothing generates attention more than a recent disaster by instilling a sense of urgency in planning to reduce future risks. But disasters do not guarantee a collective, forward-looking, comprehensive, or fair response. Significant advance planning, strong governance, and impactful leadership are needed to not just "bounce back" but "bounce forward" (e.g., Shaw 2012).

Short of the opportunistic, however, Carmin et al. (2012) and Ekstrom and Moser (2014) offer insights into local institutional factors that can support adaptive change. These include:

- A desire to demonstrate leadership in national, regional, and international arenas;
- A culture of innovation;
- Establishing connections between new (climate) risk management actions and existing (popular) programs and policies that address other problems, including poverty, pollution, sustainability, and, more generally, quality of life;
- Leadership within and across critical departments and across administrations; and
- Respected civil society champions.

Promoting these success factors in smaller coastal communities is a difficult challenge, and one not well understood in practice. Creating opportunities for community dialogue and visioning that simultaneously addresses multiple concerns (e.g., economic viability, open space, community infrastructure) is one promising approach. Role-playing, visioning dialogues, and community-based assessments are being implemented in a growing number of large and small coastal communities (Susskind et al. 2015; Webler et al. 2014; Douglas et al. 2012; Sheppard et al. 2011). While far from ensuring success, such efforts promise to increase understandings of risks and their driving forces, and to facilitate creative thinking about management strategies, develop (new) and trusted relationships, consider co-benefits, and create a legitimate, learning-oriented process for addressing complex challenges (e.g., Glavovic et al. 2015; Curtin 2014; Glavovic et al. 2005).

## 5. Conclusions

There is an internally consistent logic to the dynamics that have created the coastal risk conundrum, whereby accelerating sea-level rise combines with the underlying demographic, economic, legal, administrative, political and social drivers so as to create the worst possible sequence of outcomes. Glavocic et al. (2015) argue that the typical governance mechanisms (markets, administrative procedures, democratic politics, law, and informal governance institutions (e.g., social norms)) are inadequate to halt these dynamics or address the drivers of unsustainable coastal development. Only the intentional shifting of the underlying mechanisms, capacities, norms, and attitudes will build a different governance system, an adaptive institutional culture, improved decision-making, and ultimately safer outcomes.

The ideas put forward here aim at redirecting the deeper drivers, governance structures and capacities that shape the risk conundrum and steer us toward the future. Social experimentation will be crucial and should be pursued with some urgency (Gross and Hoffmann-Riem 2005). The key to answering the perplexing risk conundrum of exposure lies in redesigning the governance structures underlying coastal management such that they support a transformation toward greater safety and resilience (Curtin 2014). This transformation must build the long view into decision-making and demand that we grapple with the interacting scales and complexities of human occupancy of one of the most beautiful, attractive, dynamic and dangerous places on Earth.

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## **Textbox 1: Assessing Adaptation Pathways: Steps in Characterizing the Adaptive Response Space**

### **1. Identify areas for “protection”**

Identify areas able to generate/attract the necessary funds for *in situ* adaptation. Initial baseline delineation using Titus et al. (2009); Martinich et al. (2012), Strauss et al. (2012); Gittman et al. (2015); Lentz et al. (2016), and others.

### **2. Determine assessment criteria**

Establish normative criteria beyond benefit/cost ratio, involving a range of experts (science, economists, security, ethics, systems etc.) and stakeholders.

### **3. Prioritize based on urgency**

Compare level of existing protection to level of needed protection. Assess time it would take to build needed protection. Rank must-protect areas by the time available to build the necessary/desired protection in time before it is needed.

### **4. Assess pros, cons of *in situ* adaptation**

Describe pros and cons of *in situ* adaptation and how the integration of “green” infrastructure and other social/economic measures would affect outcomes. Propose “best practice” approaches for *in situ* adaptation.

### **5. Assess options for “accommodation”**

For lower-priority protection areas and for not-to-be-protected areas, describe and assess all approaches for “accommodation.” Establish normative criteria beyond benefit/cost ratio and provide “best practices” lists of approaches for accommodation (living with sea-level rise).

### **6. Determine time to abandonment**

For most-likely-to-be-abandoned areas assess time remaining before occupancy becomes untenable to establish a reasonable timeline. Consider SLR and socioeconomic, cultural, environmental factors in this determination. Then rank to-be-abandoned areas by time available and level of needed assistance.

### **7. Assess status, options, challenges and best practices**

For areas to be relocated, synthesize status, challenges, attempted/available solutions, and status of unresolved issues. Assess needs of receiving communities. Review and assess international experience on best practices, comprehensive “relocation” programs.

### **8. Assess social acceptability**

Synthesize literature on status and conditions of social acceptability of full range of adaptation options, and pathways. Consider all factors that affect acceptability (e.g., sense of place/place identity, ecological, economic, political, cultural).

### **9. Assess governance adequacy**

Consider governance, not just government. Describe/assess governance approaches. Identify “best practice” examples and innovative approaches from US and around the world.

### **10. Synthesis & research needs**

Conclude with assessment of the level of challenge the nation is facing. Assess confidence in the state of knowledge. Identify research needs to better inform adaptation pathways.