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Principles for sustainable governance of the coastal zone: In the context of coastal disasters

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ABSTRACT

As increasing numbers of the global population gravitate toward the coasts, pressure mounts on ecosystems and the infrastructure at coastal locations. In the coastal zone many problems have arisen, including coastal population growth and degradation of natural capital, from the neglect of the four capitals that enhance sustainability: natural, built, social and human. New strategies need to be devised that will allow coastal communities to continue to live in these regions without further degrading natural capital. The Brundtland Report initiated the idea of sustainability, which was further advanced at United Nations meetings in Stockholm (1972) and Rio de Janeiro (1992). Following these meetings and the adoption of Agenda 21, concern about growing pressures on the oceans lead to an Independent World Commission on the Oceans (IWCO) workshop where a number of Principles for Sustainable Governance of the Oceans (Costanza, R., Andrade, F., et al., 1998) were developed. In the light of recent coastal disasters such as the Indonesian Tsunami (2004) and Hurricanes Katrina and Rita (2005), this paper examines the current problems inherent in the coastal zone and attempts to develop new principles for sustainability using the IWCO derived principles as a springboard.

1. Introduction

With approximately 41% of the world's population living within 100 km of the coast (Martinez et al., 2007-this issue) the importance of the coastal zone and issues of sustainability are at a paramount. If the trends observed between 1990 (2 billion people living within 100 km of the coast) and 2000 (2.3 billion) continue, the UN Population Division (2001) estimates that the number of people living on and around coastlines will increase to 3.1 billion people by 2025 (an ~ 34% increase in population). This continued strain on the coastal zone calls for a set of principles for governance that will ensure its future sustainability, especially in the light of recent coastal disasters such as the Indonesian tsunami (2004) and Hurricane Katrina (2005).

2. The coastal zone

The coastal zone is not easily defined and it is of interest to government, coastal planners and managers, businesses, workers and residents. The boundaries of this zone may include both biophysical and policy-oriented definitions. The biophysical limitations of the zone may include any part of the land that interacts with tides, salinity, winds and biota of the land–sea interface (Davis and Fitzgerald, 2004). In some regions the coastal zone can be a few hundred meters wide. In others, the physical and ecological interconnections can extend the coastal zone farther inland so that it encompasses watersheds and rivers that drain into coastal waters (Beatley et al., 2002) or show the effect that large urban communities such as Los Angeles and Tokyo have on the definition of these

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boundaries. The physical components of the coastal zone include intertidal zones, coastal floodplains, mangrove swamps, estuaries, salt marshes, beaches, dunes, wetlands, barrier islands, coral reefs and tidal flats (Hinrichsen, 1988), with the coastline extending ~ 320 nautical km out to sea to edge of the Exclusive Economic Zone (United Nations, 1982). Definition of the policy-oriented boundaries, which are of relevance to coastal planning and management, may be determined by legislation. This legislation may have been influenced by distance definitions e.g. the landward limit of local municipalities that front the ocean, or according to use (Kay and Alder, 2005).

3. Problems with the coastal zone

The coastal zone has unique interactions between its terrestrial and marine environments. It is precisely because of these unique interactions that the coast has challenging management issues and other problems. Increasing coastal populations, heightened pressure on coastal resources, and the real-estate premium of coastal land has created problems in the ways in which these competing uses are managed. The first step in creating a new paradigm with which to tackle these problems is to assess the problems themselves.

3.1. *Coastal population growth*

One of the largest threats to the sustainability of the coastal zone is the growth in coastal populations. Coastal population growth increases demand for a continuing supply of clean water, waste disposal, public health, food and protection from natural disasters. There are also increased pressures on ecosystems from recreation and tourism, and from the infrastructure needed to accommodate these in the form of roads, bridges, parking lots and sewers. In the United States coastal development has reached staggering proportions in some regions. Over 800,000 new housing units are built annually on the coasts, often lacking planning to contain these residential areas, and also at a cost to wetlands and forests (Beatley et al., 2002).

3.2. *Lack of sustainable development*

The concept of sustainable development was defined in the Bruntland Report or *Our Common Future* (World Council on Environment and Development) in 1987. Since then there have been many interpretations of this phrase along with its general acceptance. Mebratu (1998) proposes that although there is agreement concerning the impending environmental crisis, there has been difficulty in attaining a coherent single definition because are three different interpretations of sustainable development: the Institutional Version (need satisfaction); the Ideological Version (a root in 3 separate liberation theories (eco-feminism, eco-theology and eco-socialism), a common ground in source, solution and the role of leadership); and the Academic Version (a science-based response from sociologists, ecologists and economists, from a reductionist viewpoint). Dodds (1997) suggests that sustainable development affirms the need to improve the well-being of the poor whilst maintaining the basis of future well-being. Perhaps Daly (1990) has the most succinct definition of sustainable development: what is being sustained is a level of physical resources and that qualitative capacities are being developed to enable the conversion of the constant level of physical resources use into improved services for satisfying human wants, and also taking into consideration *natural capital* (natural stocks that yield flows of natural resources and services without which there can be no production).

This problem of attaining sustainable development is exemplified by issues that have arisen with the National Flood Insurance Program (NFIP) in the United States (Bagstad et al., 2007-this issue). Claims on flood insurance have risen substantially, ostensibly caused by the NFIP policy that allows homeowners who were grandfathered into the scheme to rebuild their houses following flood disasters. The National Association of Realtors (NAR) states that there are 45,000 insured properties that have incurred two or more flood losses over a ten year period, at a cost of $200 million annually to the NFIP (Realtors, 2003). NAR is concerned that these repetitive loss properties cause economic harm to the NFIP. Apart from the concern over the repetitive loss claims, little attention is paid to the fact that construction of built infrastructure e.g. levees and seawalls and the issuance of flood insurance may encourage a false sense of security and further development in floodplain areas that are patently unsuitable for development.

3.3. *Degradation of coastal ecosystems*

In coastal areas, the degradation of ecosystems has increased the vulnerability of coastal towns and cities and their populations. Increasing population growth, movement of populations towards the coast and the increase in coastal development has also lead to an increase in pressure on and degradation of coastal ecosystems. Cincotta and Engelman (2000) document how growth in human population and increased use of resources per capita has impacted species and ecosystems. This degradation is reducing the long-term resilience of these systems and is thereby limiting their sustainability. Degradation of natural capital is evident in Louisiana, where a number of factors have contributed to the loss of the coastal ecosystem and may be attributed to the disastrous impacts of Hurricane Katrina in 1995 (Lotze et al., 2006). These factors include both natural (including storm events and wetland loss) and human-induced (including oil and gas infrastructure and flood control).

3.3.1. *Natural factors*

3.3.1.1. Storm events. Storm events can cause the loss of coastal land via erosion from increased wave energy, removal of coastal vegetation and saltwater intrusion into interior wetlands from storm surges. Global climate change is expected to increase coastal storm events (Michener et al., 1997; Clark et al., 1998), and these storms are often a cause of drastic changes in coastal landforms (Leatherman, 1982), where erosion is particularly prevalent in areas where vegetation has been diminished (Danielsen et al., 2005).

3.3.1.2. Wetland loss. Louisiana has lost over 486,000 ha of coastal wetland since 1930. Since the 1970s wetlands are being reduced at a rate of ~ 40–60 km^2/year (Barras et al., 1994, 2003).

The wetlands are built up as a result of deltaic processes associated with the Mississippi River. As the path of the Mississippi River has been altered by the introduction of levees, the usual distribution of sediments to the wetlands has been interrupted. This has compounded an existing natural phenomenon whereby sediments compact over time as water is expelled from the pore spaces. Tropical storm events have also contributed to land loss and erosion of barrier shorelines (LCA, 2004).

3.3.1.3. Barrier island degradation. Barrier islands perform an important function in the mitigation of natural disasters. They can help downgrade the intensity of tropical storms and hurricanes whose power decreases as they make landfall. Joseph Suhayda of Louisiana State University's (LSU) Department of Civil and Environmental Engineering estimates that the barrier islands could reduce storm surge inland by as much as 1 m (Bourne, 2000). Although barrier islands can act as the first line of defense against hurricane storm surge (LCA, 2004), the impact of successive hurricanes in the Gulf of Mexico (Hurricanes Georges, Lili and Ivan) has lead to increased erosion (U.S.G.S., 2006).

3.3.1.4. Sea level change, eustatic and relative. Increases in the concentrations of carbon dioxide in the atmosphere have led to a general trend of warming of the planet. This warming is the cause of melting of polar ice, which leads to an increase in global sea level. These eustatic sea level changes threaten the viability of many coastal cities. The decrease in suspended sediment load in the Mississippi (LaCoast, 2005) and the dumping of the majority of its current load into the trench in the Gulf of Mexico is diminishing the supply of sediments to the wetlands that can help protect Louisiana. This combined with normal subsidence due to compaction and consolidation has driven a change in relative sea level, where land level falls and sea level remains constant.

3.3.2. *Human activities*

3.3.2.1. Flood control. The levee system was developed following settlement by the French in order to limit flooding of populated areas, support navigation and protect against storm surges (Kemp, 2006). In coastal Louisiana there are approximately 3620 km of levees (LCA, 2004). The positioning of the levees has facilitated development throughout the coastal zone placing populations and property in the path of flooding caused by large storms such as Hurricane Katrina. The introduction of levees to the Mississippi River has meant an increase in coastal land loss due to lack of input from river sediments.

3.3.2.2. Navigation. As a consequence of gas and oil industry exploration and extraction, thousands of canals have been dredged through the coastal wetlands of Louisiana. Canals have had a harmful effect on wetlands by allowing saltwater intrusion and altering salinity in interior wetlands, causing flooding and increasing marsh erosion rates (Turner et al., 1994). The Times–Picayune speculated that the Mississippi River-Gulf Outlet (MR-GO), a ~ 122 km shortcut between New Orleans and the Gulf of Mexico, acted as a conduit for storm surge into the city during Hurricane Katrina. MR-GO may have acted like a funnel causing the storm surge to stack up several feet higher than in other parts of the city and causing the surge to increase its speed as it entered the Industrial Canal. Hassan Mashriqui, a civil engineer from LSU stated that the storm surge through MR-GO caused the levees to be breached (Brown, 2005). MR-GO also led to the destruction of thousands of acres of fresh and brackish marshlands as the opening of the canal allowed saltwater intrusion to destroy the fragile ecosystems. Turner et al. (1994) suggest that the backfilling of canals is a positive measure in the restoration of the coastal Louisiana wetlands.

3.3.2.3. Oil and gas infrastructure. The oil and gas fields located in coastal Louisiana spawn a vast network of pipelines, canals, and production facilities. The emplacement of these facilities and pipelines has lead to excavated material from the wetlands being dredged into banks. These banks are higher than the surrounding marsh lands and inhibit the flow of water and sediment transport which lead to periods of extended flooding which results in plant death (LCA, 2004).

3.4. *Coastal resource management*

Managing coastal resources is made more difficult by the fragmentary nature of the information available. This information is vital to understanding the interaction between the land, ocean and atmosphere in the coastal zone. This may be due to the separation of the scientific disciplines, physical, chemical and social. In conjunction with this, linkages and dissemination of information that enable collaboration between scientists, policy makers and residents in the coastal zone have been difficult to achieve. Also, the agendas of the stakeholders in the coastal zone (e.g. development of built capital for business use vs. residential use) can lead to conflict over land-use, and natural, institutional and financial resources. Furthermore, the problem of fragmented responsibility among various government agencies has resulted in a lack of management integration, which has lead to needlessly reactive management. This has included: responding to problems after the fact that could have been anticipated and avoided; cumulative impacts: many minor decisions made at different levels of government add up to major problems; reassignment of problems from one area to another; the prevalence of short-term economic issues and disjointed geographical planning (EUCC, 1998). Some of the management problems outlined here are exemplified in New Orleans and particularly the city and the state of Louisiana's competency in dealing with Hurricane Katrina. The city of New Orleans was ill prepared for the devastation that Hurricane Katrina caused. This was further illustrated by the minimal communication between institutional organizations regarding preparations for emergency situations. This ranged from the inadequacy of radio communications, to a national level where the Federal Emergency Management Agency (FEMA) was not prepared for the scale of the disaster.

3.5. *Mitigation planning*

The importance of a viable and executable emergency preparedness plan has become acutely more significant since the advent of Hurricane Katrina. Public officials in New Orleans

had more than a week to prepare for Hurricane Katrina and 72 h to prepare themselves on a local, state and regional level. The officials also had access to decades of hurricane data for the Gulf of Mexico. The Hurricane Katrina event matches "Scenario 10 – Major Hurricane" in the "15 National Planning Scenarios" document (The Homeland Security Council, 2004). So, what went wrong? Although New Orleans did have an emergency preparedness plan in place, miscommunication between the various agencies of government both at state and national levels hindered the ability of the authorities to be effective (Baker and Refsgaard, 2007). Professor John R. Harrald, The Director for the Institute for Crisis, Disaster, and Risk Management at George Washington University, testified before a House Committee on Government Reform Hearing in September, 2005. Harrald stated, "The response capabilities and resources of the local jurisdiction (to include mutual aid from surrounding jurisdictions and response support from the State) may be insufficient and quickly overwhelmed. Local emergency personnel who normally respond to incidents may be among those affected and unable to perform their duties." In New Orleans, many of the first responders such as police and firefighters were themselves homeless, and it took several days for federal and state resources to be established. He noted that a total breakdown in communications between agencies was responsible for the lack of effectiveness and that the lack of ability to be adaptive to the situation led to the slowness of the response (House Committee on Government Reform Hearings, 2005).

In an interview on NPR in September 2005, Gavin Newsome, Mayor of San Francisco, emphasized the importance of people being trained and prepared for an earthquake. He stated that many of the first responders for an emergency live outside of the city, so that for the first 72 h of a disaster, residents will have to fend for themselves and should ensure that they have food, water and medical supplies and be trained in CPR. Residents will be organized block by block in the city so that they can help themselves until the police, fire fighters and state and federal government can respond (NPR, 2005). This level of preparedness may have been useful in New Orleans, considering that the approximately one third of New Orleans households who did not own a car (USCB, 2000) needed to be aware of a predetermined plan for evacuation.

3.6. *Socio-economic Issues*

In the wake of the 2004 and 2005 hurricane seasons, a discourse should ensue concerning land-use planning, zoning and coastal development. David C. Kyler, Executive Director for the Center for a Sustainable Coast, states that local governments often make planning decisions on a case-by-case basis, with no long-term policy framework, often driven by the demands of private development and with no community consensus. The result of this approach to land-use is that a region grows chaotically without thought for the stress it places on the regions natural resources, the sustainability of the development, or for the safety of the populace in areas that are prone to coastal hazards (Kyler, 2005). As coastal populations continue to grow, the issues regarding land-use in the coastal zone will need to be addressed.

3.7. *Decision-making and weather-related catastrophes*

The last four decades of hurricane seasons in the U.S. have seen an exponential increase in the dollar value of damages. The average annual losses from natural hazards (property and crops), exceed $7.6 billion (Cutter and Emrich, 2005). Webster et al. (2005) indicate that although the link between global warming and increased hurricane activity is currently tenuous, worldwide data indicates that there is a 30 year trend towards an increased frequency and intensity of hurricanes. Cutter and Emrich (2005) attribute much of the cause of increasing disaster losses to the fact that increasing numbers of people and property are put in harm's way due to population growth, migration, and development of built capital in hazard-prone coastal areas.

4. Sustainable or desirable scale?

As a precursor to examining the Principles for Governance of the Coastal Zone it may be beneficial, using New Orleans as a case study, to consider what kind of scale is favored: sustainable or desirable scale.

Conceptually, desirable scale occurs when the diminishing marginal benefits of growth in built capital are equal to the rising marginal costs of the natural capital sacrificed to achieve that growth. Growth beyond this point diminishes the quality of life that can be sustained across generations. In this context, quality of life entails some kind of human needs and well-being assessment. Conversely, Daly and Farley (2004) give a working definition of sustainable scale in their book "*Ecological Economics*". "The goal of sustainable scale requires a social or collective limit on aggregate throughput to keep it within the absorptive and regenerative capacities of the ecosystem" (p. 363). In New Orleans, the aftermath of Hurricane Katrina firmly brought into public view the long-known inequalities of that city, and demonstrated the difficulty in determining sustainable or desirable scale. Whose quality of life will be taken into consideration? Perhaps the guiding principle for the reestablishment of New Orleans should manifest itself in the form of sustainable scale. Hurricane Katrina demonstrated that New Orleans and the state of Louisiana were not operating at a sustainable scale. For example, the exploration and excavation activities of the gas and oil industries in coastal Louisiana had undermined the sustainability of the Louisiana Gulf Coast by degrading the wetlands, which in turn exacerbated the impacts of Hurricane Katrina (Fischetti, 2005).

Sustainability is a desirable objective for coastal zones that is not presently embraced by all concerned parties. Davos (1998) suggests that this may be a function of coastal zone management policies which are socially constructed. The effective implementation of these policies relies on the cooperation of *all* stakeholders and should be achieved via a process of negotiation amongst these stakeholders. With Daly (1990) in mind, it seems as if this strategy should be achieved within some sustainable scale, i. e. human scale should be limited, if not optimally, then within the carrying capacity of the ecosystem. But, we can still ask, "how do we create the most of what is desired from what is available?" In the current discourse regarding the rebuilding of New Orleans, the option of not rebuilding the city has been neglected as a topic of

Table 1 – Principles for the sustainable governance of the coastal zone

Principle 1: sustainability	The use of natural capital within the coastal zone should be achieved sustainably and in an efficient and socially equitable manner.
Principle 2: adaptive management	Decision-makers should have the ability to integrate ecological, social and economic information, and to have the flexibility to cope with changes in the environment, e.g. coastal hazards, across varied levels of government.
Principle 3: participation	Stakeholder participation is vital in the decision-making process regarding environmental resources in the coastal zone
Principle 4: integration	Decision-making regarding the coastal zone should integrate policy with input from the scientific community.

discussion. In light of this, and with residents, local, state, regional and national government and private interests all looking towards the rebuilding of the city, the application of the principles on a sustainable scale is imperative.

5. How do we achieve sustainability?

5.1. *Paradigm shift*

At present, in the political and economic arena, the market typically drives decision-making. We conjecture that sustainability can only be achieved with a shift in the existing political and particularly economic paradigm. Adaptation of Costanza's (2001) model regarding a new vision of the economy could provide the basis for a paradigm shift. The starting point for this paradigm shift could be that of a shared vision of the desired goal as envisioned by Weisbord (1993) and Weisbord and Janoff (2000). Costanza's model views the world as a "full-world era", where natural capital is the limiting factor. In this "era", maximization of productivity of natural capital is paramount, and in concert with this there should be an adequate valuation of that natural capital and the associated ecosystem services. This alternative paradigm may be envisioned through the three types of values outlined by Costanza (2001) (Table 1). "*Homo economicus*" is the model of human behavior where humans act in their own self-interest, the level of discussion required is low and it is assigned an efficiency-based value. This may be seen as a market-driven paradigm. "*Homo communicus*" is involved in discussions with the community regarding future choices by the community, who strive to come to a consensus that is inclusive of everyone, including future generations. The fairness value relates what is fair to all members. "*Homo naturalis*" operates as if decisions being made are in the context of the whole ecosystem, where individual items are assessed by their contribution to ecological sustainability. The challenge in attaining sustainability, once the appropriate scale has been chosen, is to see a transition between these different states of being. Presently, it seems as if many decisions are made in the *Homo economicus* mode, with some attempts to have decisions made at a community level. In order to maintain sustainability in the coastal zone, there needs to be a shift in decision-making style, to one that incorporates *Homo communicus* and *Homo naturalis*. To put this in the context of New Orleans, decisions about rebuilding the city and restoration of the wetlands would be made on a community level, i.e. inclusive of all the stakeholders involved, with an eye towards having some sense of the value of the system as a whole. In Louisiana, some steps were made towards this ideal with the development of Coast 2050 (Louisiana, 1998). This report was developed through the cooperation of the governor's office, Louisiana's Department of Natural Resources, the U.S. Army Corps of Engineers, the Environmental Protection Agency, the Fish and Wildlife Service and the 20 coastal parishes. This demonstrates that cooperation between a set of diverse agencies is possible, and that this could be used as a model for future decision-making.

6. Principles for governance of the coastal zone

In 1983 the United Nations appointed an international committee to propose strategies for sustainable development, ways in which to improve human quality of life without threatening the local and global environment in the long-term. "*Our Common Future*", also known as the Brundtland Report, documented these strategies. United Nations Conferences in Stockholm (1972) and Rio de Janeiro (1992) considered "the need for a common outlook and for common principles to inspire and guide the peoples of the world in the preservation and enhancement of the human environment". The Rio meeting established Agenda 21 which sought to address current environmental problems, prepare for the problems of the upcoming century, and move towards a global consensus on and a political commitment to development and environmental cooperation that integrates international, regional, sub-regional, non-governmental organizations and public participation. Following in the footsteps of Stockholm and Rio the Independent World Commission on the Oceans (IWCO) set out to inform the public and national leaders of the important role that the oceans play in the survival of the planet, to the pressures that the oceans are facing and to promote sustainable use of the oceans. In response to this six core principles towards achieving sustainable governance of the oceans were established. These principles were developed incorporating various disciplines, stakeholder groups and generations via the model of adaptive management (Costanza

Table 2 – Value-based paradigm shift (adapted from: Costanza and Folke, 1997)

Value base	Participant	Preference basis	Level of discussion required
Efficiency (E-value)	*Homo economicus*	Current individual preferences	Low
Fairness (F-value)	*Homo communicus*	Community preference	High
Sustainability (S-value)	*Homo naturalis*	Whole system preferences	Medium

et al., 1998). Taking into consideration the Principles for Governance of the Oceans, this paper seeks to develop a set of Principles that will provide a framework within which to govern coastal zones sustainably, particularly in the light of recent coastal disasters such as Hurricane Katrina (2005) (Table 2). We will expand these principles and consider practical applications of them, particularly in the light of Hurricane Katrina.

6.1. *Principle 1 – sustainability*

There are several key issues that must be addressed in order to achieve sustainability carrying capacity; risk, vulnerability and resilience; mitigation planning; full-cost accounting; and investment in human and social capital.

6.1.1. *Carrying capacity*

With the continuing increase in coastal population and density, the issue of the carrying capacity and hence sustainability of the coastal zone becomes imperative. Garrett Hardin defines carrying capacity in his essay "Ethical Implications of Carrying Capacity" as "the maximum number of a species that can be supported indefinitely by a particular habitat, allowing for seasonal and random changes, without degradation of the environment and without diminishing carrying capacity in the future" (Hardin, 1977).

In order to attain sustainability in the coastal zone, it is necessary to understand this concept of carrying capacity in the context of humans and their relationship with the environment, and also to make long-term policies that take this into account. The effectiveness of sustainability through coastal management plans is reliant on wise management of ecological systems whose resources are finite. Through improvements in resource management, conservation and economic policy changes, some increase in human population and the economy may be viable (Arrow et al., 1996). As carrying capacity is somewhat fluid by nature it is dependent on production, consumption and the interaction between biotic and physical environments (Arrow et al., 1996). The difficulty of assigning a specific number for human carrying capacity led Arrow et al. (1996) to suggest that resilience (a measure of the magnitude of disturbance a system can sustain) of the ecosystem may be a better measure. This idea of achieving sustainability via recognition of the limitations of natural capital is also echoed by Ress and Wackernagel (1996). They suggest that an "ecological footprint" analysis, "the corresponding area of productive land and aquatic ecosystems required to produce the resources used, and to assimilate the wastes produced, by a defined population at a specified material standard of living, wherever on Earth that land may be located," is necessary in order to assess carrying capacity. There is, among these analyses, an agreement that carrying capacity cannot be attained solely through technological advances.

The assessment of sustainability via the use of carrying capacity may be quantified through the use of data sets such as the Environmental Sustainability Index. Utilizing numerous variables (e.g. energy consumption, surface water availability) and indicators (water quantity, eco-efficiency), this index enables some quantification of the environmental impact of nations (Esty et al., 2005). Through indices such as these nations could assess their environmental impact, and their ability to sustain current populations given finite natural capital, and develop strategies and policies to enable them to operate sustainably.

6.1.2. *Risk, vulnerability and resilience*

The potential for the occurrence of coastal hazards makes it necessary to consider the risk, vulnerability and resilience of communities on both a physical and socio-economic level. Risk can be considered as the losses associated with a coastal disaster and vulnerability refers to the effects of the event on the characteristics of the society or environment (H. John Heinz III Center for Science Economics and the Environment, 2000). The way in which a society views risk and vulnerability is vital to the decision-making process regarding mitigation. An adaptation of Principle 2 is useful in this context, as policies concerning built capital need to be flexible enough to ensure that the region does not increase its vulnerability to coastal hazards. Coastal development should be carefully planned (Principles 1) and decided on by all the stakeholders who will be affected (Principle 3).

Risk and vulnerability assessments should be taken into consideration when deciding on future development plans in regions that are vulnerable to coastal hazards. These assessments could then be used to guide land-use planning and zoning and building codes, something that is critical in coastal regions. Land-use planning and zoning are important tools and they can be a powerful regulatory technique that can demarcate specific land and water areas for specific uses. These tools could also be used to control development in areas that are of high risk to coastal hazards. At this juncture, the transition from *Homo economicus* to *Homo naturalis* becomes extremely important. Decisions about where to build in regions that are affected by coastal hazards should be made by consensus, with appraisal of appropriate scientific information, with the ecosystem as a whole in mind, and not purely dominated by economic motives. If decisions are made to continue to build in areas of high vulnerability to coastal hazards, as in New Orleans, then building codes can be another strategy that local and state agencies can utilize. Coastal structures can be designed to better withstand hurricanes and storm surges.

Resilience was defined by Holling (1973) as "…the ability of a (system)…to absorb changes of state variables, driving variables and parameters and still exist." With the concentration of populations along the coasts, and with the high potential of damage from coastal hazards, it would be prudent for decision-makers to encourage a shift away from vulnerability and towards resilience, especially with regards to built and natural capital and to a lesser degree social capital. Resilience in terms of coastal hazards may be seen as the ability of the social-ecological systems to efficiently absorb the impact of reoccurring events such as hurricanes. Resilience is also a measure of the ability of a system to self-organize, and to adapt and learn from these events (Adger et al., 2005; Baker and Refsgaard, 2007). Resilience can be built by ensuring that in areas affected by hurricanes there are feasible mitigation plans and that attention is paid to the scientific community about potential hazards. Early warning systems also need to be in place so that institutions can manage crises adaptively (Principles 2 and 4) and seek to confine the impact of these

events (Adger et al., 2005). Adger et al. (2005) make some suggestions of how social-ecological resilience can be enhanced (Table 3).

The priority for enhancing resilience should be the removal of things that destroy natural capital and thereby reduce resilience. Adaptive management systems at various levels of governance (Principle 2) are vital in order improve the capability of systems to cope with coastal hazards (Adger et al., 2005).

6.1.3. *Mitigation planning*

Given the susceptibility of coastal areas to natural hazards like hurricanes and tsunamis, and the floods that characteristically result in the wake of such events, the integration of hazard mitigation into land-use policy and evacuation planning is key to governing in a sustainable way. Mitigation planning may be seen as the resilience equivalent for built capital. "Any action taken to reduce or eliminate the long-term risk to human life and property from hazards" is FEMA's working definition of mitigation (Schwab et al., 1998). Mitigation techniques are broad in scope, cost and creativity. Some examples are listed in the table below, but innovative, organic ideas born of collaborative discussion at the community level should not be overlooked (Table 4).

Characterization of intensity and likelihood of hazard events, vulnerability of populations, property, facilities and infrastructure to these hazards, and risk associated with hazard probabilities are the tools that can allow decision-makers to inform their choices to maximize mitigation.

Table 3 – Examples of local- and regional-scale actions to enhance resilience in social–ecological systems exposed to abrupt change

Elements of vulnerability	Local action	National and international action
Exposure and sensitivity to hazard	Maintenance and enhancement of ecosystem functions through sustainable use	Mitigation of human-induced causes of hazard
	Maintenance of local memory of resource use, learning processes for responding to environmental feedback and social cohesion	Avoidance of perverse incentives for ecosystem degradation that increase sensitivity to hazards
		Promotion of early warning networks and structures
		Enhancement of disaster recovery through appropriate donor response
Adaptive capacity	Diversity in ecological systems	Bridging organizations for integrative responses
	Diversity in economic livelihood portfolio	Horizontal networks in civil society for social learning
	Legitimate and inclusive governance structures and social capital	

From: Adger et al., 2005.

Table 4 – Mitigation techniques (adapted from Burby, 1998)

Type of tool	Specific examples
Planning	Local emergency management plan
Development regulations	Hazard appropriate zoning ordinances
Building code standards	Special hazard resistance standards
Property acquisition	Building relocation, development rights
Facilities policies	Location requirements for critical facilities like water treatment
Economic incentives	Impact taxes
Education/ communication	Public information programs

However, analyses of vulnerability and risk are much less common than simple hazard identification studies (Burby, 1998), so most coastal communities are currently limited to decisions based on locations that will be impacted by hazards of varying intensities, and the probability of occurrence of each hazard intensity. In order to evaluate alternative mitigation options; estimate the societal impacts of various hazard possibilities; attempt to categorize expected damages to various types of capital; predict equitability issues in regards to distribution of disaster impacts; prioritize evacuation strategies; and plan for efficient allocation of post-disaster aid; at least a vulnerability assessment is necessary. A risk assessment, considered the most sophisticated level of hazard prediction, makes quantitative estimates of damage, injuries, and costs including their magnitude and probability for a specific geographic area over a given period of time, but may be less useful to local authorities than a less probabilistic vulnerability assessment because of limitations in their understanding and skills related to probability theories (Burby, 1998). On the local level, utility of these hazard assessments is dependent on precision of data; while coarse data is useful for large-scale, regional assessments and for building public support, it may be meaningless for small-scale, localized land-use management and policy creation because it can obscure political justification for differential treatment of land parcels, and it does not allow for equitable protection of all those subject to regulated land-use (Burby, 1998). Development of scale-appropriate data may be too costly for many municipalities to undertake without the support of outside funds.

6.1.4. *Full-cost accounting*

To achieve sustainability a number of measures can be used that incorporate environmental responsibility and full-cost accounting (see Gaddis et al., 2007-this issue). Full-cost accounting is an attempt to ensure that the costs and benefits associated with the use of ecosystem resources are borne by the appropriate parties. It may be achieved in the form of taxes, incentives or other economic instruments (see Bagstad et al., 2007-this issue). These instruments can be used to encourage changes in behavior and can help to control external costs such as damage to the environment, and also

to encourage companies to attain economic goals in a cost effective manner (Sorenson, 1997). These economic tools include (Sorenson, 1997):

Eco-taxes polluters pay taxes per unit of pollution in proportion to the social costs incurred.
User charges users are charged a fee that covers the cost of using the service or product.
Subsidies companies are given remuneration for producing or using products that are less harmful to the environment.
Rights-based instruments limited rights to use or pollute environmental resources.
Tax incentives government can give tax incentives to encourage investment in projects that are considered environmentally friendly.
Environmental bonding this requires potential polluters to post a financial bond to cover any environment degradation associated with their activities (Costanza et al., 1998).

Sustainability, restoration and maintenance of natural capital may be achieved through the utilization of these types of instruments.

6.1.5. *Human and social capital*

In areas that are subject to coastal hazards, it is necessary to enrich social capital by building community to both maintain sustainability and to increase resilience against hazard events. Cohen and Prusak (2001) define social capital as "… the stock of active connections among people: the trust, mutual understanding, and shared values and behaviors that bind the members of human networks and communities and make cooperative action possible." It is these networks and connections between people and institutions that help build resilience and aid in the adaptive management of coastal regions. Additionally, education and training are important investments in human capital and may also enhance the ability of communities to adapt to living in areas affected by coastal hazards. The health of the individuals within a community also impacts vulnerability, which affects the community's ability to respond flexibly to crises (Mendis et al., 2003). Also, the promotion of socially and economically sustainable livelihoods can increase the resilience of a community, particularly if this is provided through low-impact economic activities that do not degrade natural capital.

Putnam (2000) also suggests that people whose lives are enriched by social capital cope better with unexpected events. Communities with well-functioning information networks and institutions have a greater capacity to adapt to change, and the participation of all stakeholders in the decision-making processes will increase the resilience of the community. The ability to include all members in decision-making is what will aid communities that continue to live in regions with a frequent occurrence of hazards. They will increase their ability to cope with and quickly adapt to the challenges provided by coastal disasters.

Paralysis and associated time delays relating to mitigation planning, solidification of post-disaster response and recovery priorities, can be especially costly when communities hit by disasters are forced to deal with their ramifications while debate of policy options is still underway. In these circumstances, community solidarity is likely to be eroded by ad hoc, rushed decisions characterized by crisis (Schwab et al., 1998). Conversely, when the guidelines for decisions have been publicly informed and clarified prior to a disaster, public confidence and therefore social capital are likely to be preserved and even bolstered. Natural capital protection guidelines may be especially important to define pre-disaster because they have been historically plagued by low priority, especially when human safety and economic prosperity are in danger and perceived as unrelated to ecological health (Vig and Kraft, 2005).

Finally, many coastal areas with high vulnerability to hazards and low capacity for resilience may wish to implement innovative policy changes, but lack the resources needed for research and development. Specifically, some southern states in the U.S., and developing countries in Asia and the Caribbean are likely to face some aspect of this problem. Federal and international consideration should be given to addressing technical and monetary needs for shifts to more sustainable public policy in these regions since hazard intensity and probability is likely to increase due to carbon emissions produced by less hazard prone regions of the world (Webster et al., 2005). In the United States, use of the Coastal Zone Management program (CZM) may be one way to achieve this (see Bagstad et al. (2007-this issue) for a brief description of CZM). Fair distribution of the costs of carbon would call for states with abundant resources and high carbon emissions to allocate proportional aid to states with limited resources but high vulnerability to global warming related storms.

6.2. *Principle 2 – adaptive management*

The concept of adaptive management was first envisioned in the 1970s as a response to sustainability strategies emerging out of The Brundtland Report. A paradigm shift occurred which redefined the role of humans as being within the ecosystem rather that outside of it. Management goals were refocused toward long-term health of the ecosystem, and the uncertainties within this required new skill sets that adaptive management could provide (Mendis et al., 2003). Holling (1978), followed later by Walters (1986), articulated the core ideas as an alternative to the static, inflexibility of some environmental management plans. Adaptive management encompassed the idea that the non-linear nature of ecosystems warranted a flexible management approach through learning from operational management experience as an ongoing, adaptive and experimental process (Holling, 1978; Walters, 1986). More recent work by Berkes and Folke integrates social dimensions such as trust building (Berkes et al., 2001), institutional linkages (Berkes, 2000), and bridging organizations (Folke et al., 2005).

Adaptive management is an essential factor in achieving sustainability, and it provides the opportunity for all levels of government to make decisions about managing the coastal zone and its associated problems, especially with regards to coastal hazards. A range of knowledge is necessary in order to have the flexibility to make decisions regarding coastal hazards, and an array of both skilled and trained personnel are needed for the decision-making process at different levels of governance (local, regional, state) (Mendis et al., 2003). Another important facet of adaptive management is the

ability to address broader social concepts that enable ecosystem-based management (Dietz et al., 2003; Olsson et al., 2004; Folke et al., 2005). Murray and Marmorek (2003) developed what they call "the adaptive management cycle". We use this concept as a framework within which to integrate the current discourse on adaptive management (Berkes et al., 2000; Brown, 2002; Folke et al., 2005; Olsson et al., 2004; Robinson, 2004) (Fig. 1). This cycle incorporates a number of measures designed to enable efficient and responsive adaptive management. These range from understanding and quantifying the limits of current resources to accepting the level of uncertainty inherent in the ecosystem. Adherence to these various measures should enable all interested stakeholders to be involved and for institutions to be able to respond to hazard events in the coastal zone effectively.

6.3. *Principle 3 – stakeholder participation*

Stakeholder participation goes hand-in-hand with adaptive management and incorporation of stakeholder values into coastal zone management plans and has been identified as a desirable goal in achieving sustainability (Gregory and Wellman, 2001). Advantages of multi-body participation include the ease of informing, involving and educating the public; increased transparency in decision-making; and multiple viewpoint amalgamation (Perkins, 2004). Davos (1998) suggests that coastal zone policies are socially constructed and that effective implementation of these policies depends on the voluntary participation of stakeholders who often have disparate priorities and interests. This issue of stakeholder participation is particularly relevant in coastal areas given that 41% of the world's population now resides there, densely packed into communities that are increasingly diversified in educational background, wealth, trade, political orientation, age, religion and ethnicity. Accordingly, it is necessary to develop linkages, new methods of information dissemination and tools that enable the integration of and dialogue between interested parties.

Stakeholder participation can be undermined by the use of expert-based policy analysis where a top-down method of the dissemination of information often fails to inform and educate stakeholders (Gregory and Wellman, 2001). They are often included not as active agents but in a passive manner such as via cooption (Brown, 2002). Brown (2002) and Davos (1998) suggest that there can de a disparity of both power and knowledge between some stakeholders, but that empowerment can aid local people to influence policymakers and implement decisions. One suggestion for improving linkages between various groups (local, regional and national) is the enactment of state level legislation which can encourage the development of local institutions (Berkes, 2002). Local-level institutions often respond to environmental feedbacks faster than state agencies do, and conversely if decision-making is not centralized, dissemination of feedback may be lost (Berkes et al., 2000). Cross-scale linkages of groups across various levels, local, regional and state, can also help with knowledge dissemination and increase stakeholder participation. Co-management, along with multi-stakeholder bodies, enables the development of forums for negotiation and resolution (Berkes, 2002). Berkes (2002) also suggests the idea of institutions that help with development and empowerment of local groups.

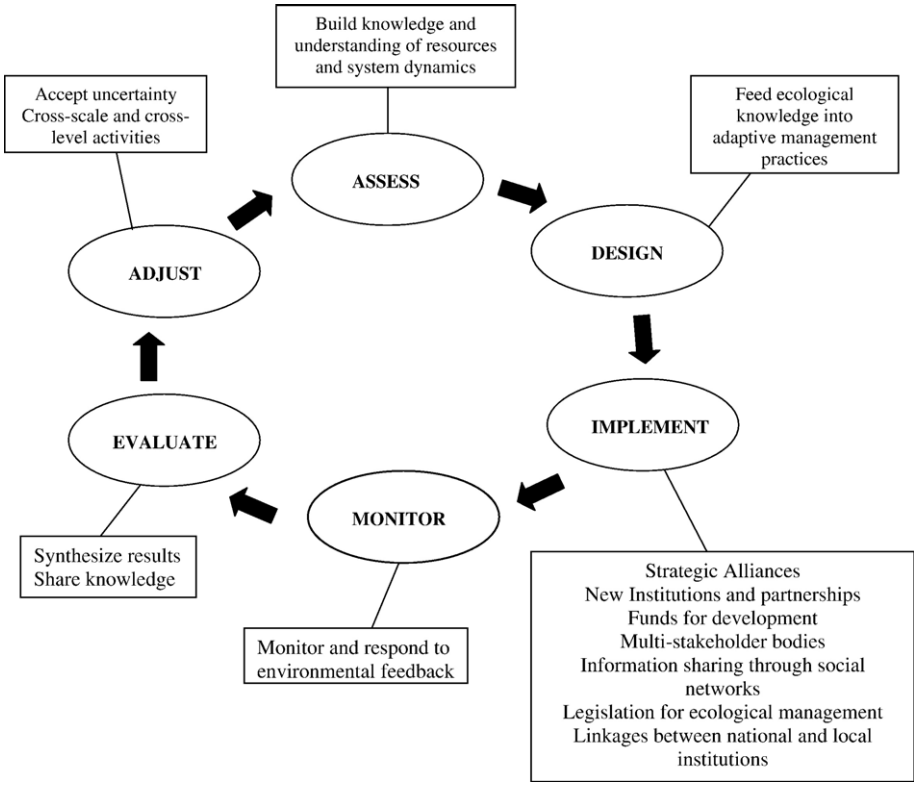

Fig. 1 – Strategic application of the adaptive management cycle. (Modified from Murray and Marmorek, 2003).

Although the road to stakeholder participation is not paved with gold, it seems that dialogue between those parties with a vested interest of the outcome of policies, and involvement in the decision-making process, can assure locally-appropriate policies. Public involvement and education are important aspects of sustainability in the coastal zone.

6.4. *Principle 4 – integration*

As has already been outlined, sustainability can be achieved with a combination of strategies including adaptive management and stakeholder participation. The concept of integration has its origins in the Coastal Zone Management Act of 1972. Integrated Coastal Management (ICM) came out of this initial act, and in the 1980s became more accepted following the adoption of Agenda 21 by the United Nations Conference on Environment and Development in Rio de Janeiro (1992). One of the central themes of ICM is integration: interdisciplinary, a comprehensive approach to coastal management that involves scientific, engineering, economic, institutional/political, legal, and social/cultural considerations; and intersectoral, pertaining to management of activities within the coastal zone (Knecht and Archer, 1993). We believe that this multi-disciplinary approach will promote sustainability in the coastal zone.

To further understand the relationship of scientific research to sustainability, we will examine the role of science in decision-making processes that are relevant to the coastal zone in the light of climate change. In 2001 the Intergovernmental Panel on Climate Change (IPCC) summarized scientific evidence that suggests that climate is changing and that human activity is exacerbating natural changes in the climate (Vellinga and Klein, 1993). One of the ramifications of this change in climate is sea level rise, which will affect many coastal areas.

Scientific research can be another tool in the belt of policy-makers, governmental agencies and other stakeholders with which to develop an integrated policy for sustainability of coastal zones. To incorporate all of the aforementioned strategies a framework for sustainability can be developed that includes economic evaluation, stakeholder participation, integrated modeling and evaluation of multiple criteria (Turner et al., 2000). Also of importance in this process is the ability to create policy of a transdisciplinary nature. This policy should be informed by local agencies and stakeholders, regional and state organizations, and the scientific community. The information generated regarding a specific problem in the coastal zone needs to be disseminated in a manner that can be digested by all concerned parties (Turner, 2000).

The role of science in coastal zone policy is exemplified by the IPCC. The Panel has developed a "common methodology" for the coastal zone pertaining to climate change. The objectives of this methodology are to assess vulnerabilities to sea level rise; understand vulnerability vis à vis socio-economic factors; evaluate feedback and responses in order to develop mitigation strategies; and to evaluate the capacity of a nation to implement response within a coastal management plan (Vellinga and Klein, 1993). In relation to climate change, Pernetta and Elder (1992) indicate that further understanding of coastal zone processes and improved global impact models will enable policy decisions to be made that are based on a scientific assessment of coastal vulnerability. Michener et al. (1997) echo this by suggesting that understanding climate change and creating policy towards resilience will be an interdisciplinary affair where impediments to data sharing will be removed, thus allowing a more efficient propagation of information. The IPCC methodology can be of use when developing coastal management plans for sustainability. One strategy for building sustainability in coastal zones is to build resilience, both social and ecological. This can be achieved through integration of institutions and individuals in a form of co-management. Stakeholders, scientists and government agencies act collectively to develop policy for resource management, to build resilience (Tompkins and Adger, 2003) and develop locally-appropriate policies.

Clark (1998) suggest that "the distinction between science and policy roles in modern natural resource management is both very important and very difficult to define." Policy-makers and scientists do have different roles, but, in order for the coastal zone to be managed and governed sustainably there needs to be integration between disciplines, cross-scale linkages, and dissemination of information between all parties.

7. Conclusion

With increasing population growth and pressure on ecosystems within in the coastal zone, the importance of nations developing plans that promote sustainability becomes increasingly essential. In regions that are vulnerable to recurring coastal hazards, such as The Gulf Coast of the United States, developing and implementing sustainable and adaptive coastal management plans should be an imperative. The outlined principles can act as a framework for the development of these plans. Development of the economic, human and social capitals, with an emphasis on natural capital, improved stakeholder participation and integration amongst the various actors will also facilitate the successful application of the principles, and provide tools with which coastal areas can adequately prepare for future coastal hazards.

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