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The coastal syndromes and hotspots on the coast

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ABSTRACT

Human intervention has resulted in a number of global and river syndromes that are mirrored by coastal syndromes caused by erosion, subsidence, salinization of aquifers, urbanization, eutrophication, invasive species and over exploitation of natural resources. These problems are now global, with few coastal zones remaining unaffected and pristine. However, the problems are particularly severe at "hotspots" in the coastal zone. These include river-mouth systems where fluxes of water, sediment, fertilizers and contaminants are focused; urbanized coasts and megacities where vulnerable populations are concentrated; Arctic coasts where the effects of climate change are accelerating a fundamental state change; and, at low lying coasts that are at risk of flooding, storm surges, sea-level rise and subsidence such as Micronesian island states where managed realignment and setback is not an option. A range of societal responses and appropriate governance frameworks will be necessary to treat the coastal syndromes.

1. Introduction

Schellnhuber et al. (1997) have identified a number of syndromes of global change where they stress that the symptoms and their interactions depend on geographical location.

Although Meybeck (2003) has analyzed river-basin syndromes, the approach has not been applied to the coast. The goal of this paper is to explore what are the common coastal problems and challenges at the global scale and to provide a broad overview of coastal syndromes. The coast is a complex biophysical system affected by the influence of land, sea and air. The human dimensions of coastal societies impose yet more layers of complexity to the system.

The paper then focuses at a smaller scale on "hotspots" on the coastal zone, coasts and coastal populations that are particularly vulnerable to global change (Halpern et al., 2009) and coastal syndromes. Finally, the paper looks at some of the possible strategic solutions that address a suite of coastal symptoms often common to several coastal syndromes. These are the responses of society to the coastal syndromes.

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2. The river basin syndromes relative to the coastal syndrome

The river basin syndromes listed by Meybeck (2003) have parallel consequences on coastal systems. Fig. 1 shows a diagrammatic representation of many of the common river syndromes. Many of the coastal problems have their origin in the catchment and the way that humans have modified and changed the river inputs into coastal systems (Meybeck, 2003; Li et al., 2007). Unfortunately, these coastal problems often act in synergy on the coastal zone, which is then subjected to multi-stressors, such as when flood risk and erosion are increasing along the same coast (Dawson et al., 2009).

3. The coastal syndromes

The type of problem in the coastal zone varies from simple problems, such as dealing with a point source, to more complicated problems, such as dealing with diffuse pollution, and also complex problems, such as coping with global change. Unfortunately, a coastal syndrome is usually a "wicked" problem (Mee, 2012) resulting from the action of synergetic multi-stressors, many of these resulting from global change. Table 1 maps coastal changes on the list of Global changes in Schellnhuber et al. (1997).

As human activities increase in the Anthropocene (Steffen et al., 2007), there are many examples and case studies in the coastal zone that illustrate the coastal syndromes. While some coastal

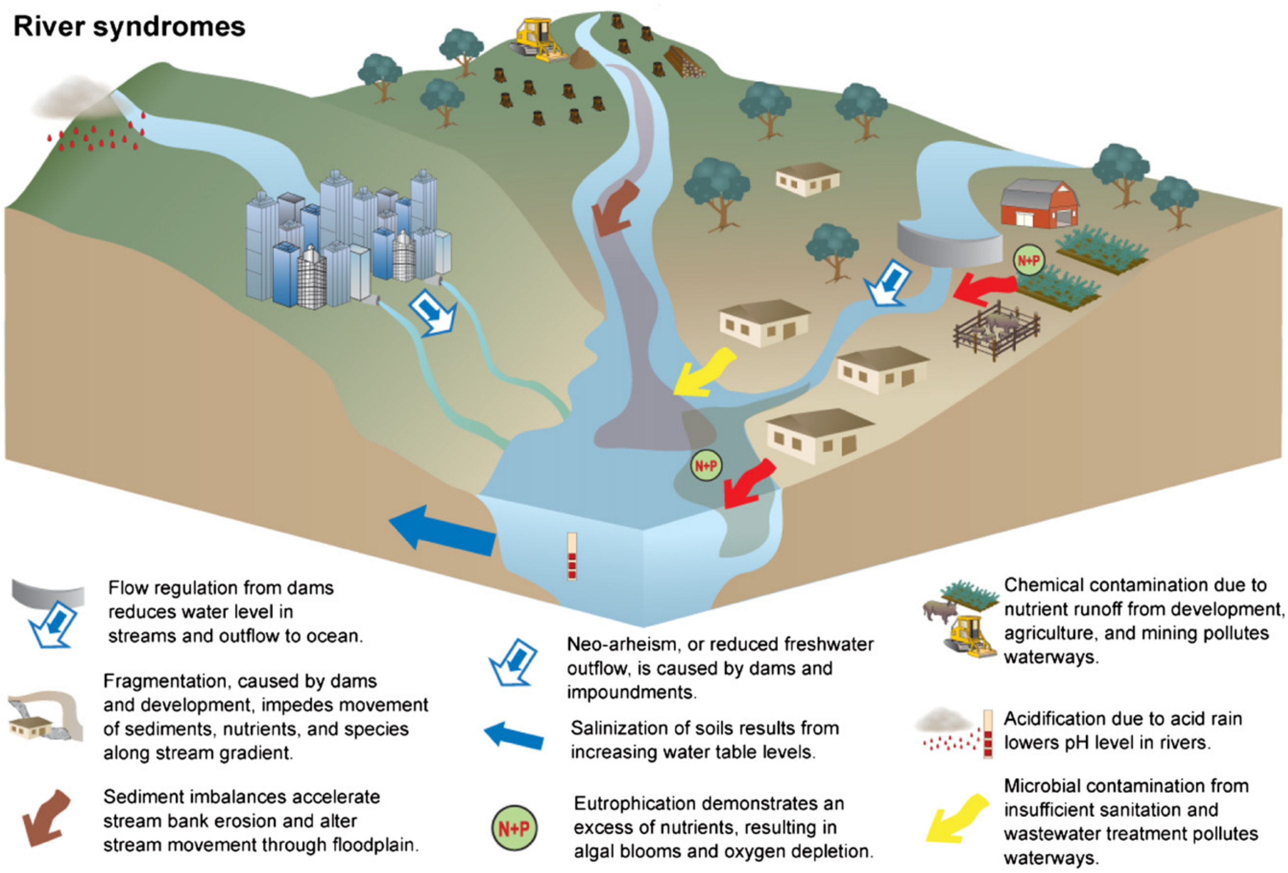

Fig. 1. Common global river syndromes.

problems, such as oil spills in the Gulf of Mexico or coral bleaching, receive much media attention, the disappearance of other key coastal habitats such as seagrass meadows goes largely unreported (Orth et al., 2006; Waycott et al., 2009).

Some well-known coastal syndromes with well documented case studies throughout the world include:

- *Sediment syndrome*: from sediment trapping by damming of rivers and the physical disruption of the coastal dynamics by coastal engineering, (e.g. Nile, Mar del Plata), as well as subsidence (e.g. several Deltas, Venice);
- *Water syndrome*: such as the over-extraction of water from coastal aquifers, decreased river-flow and ageing of water at the river-mouth from damming, (e.g. Changjian delta);
- *Eutrophication syndrome* from agriculture, animal rearing, processing of organic matter and sewage, (e.g. Black Sea, Gulf of Mexico, Baltic Sea);
- *Coastal land-use syndrome* such as the destruction of coastal forest, mangroves, salt marshes and wetlands, (e.g. shrimp farming ponds in Thailand, Honduras, Brazil);
- *Coastal urbanization syndrome* in a flood prone, low-lying coastal zone, (e.g. the Netherlands, Venice, New Orleans), on marginal land, (e.g. Dubai), as well as coastal megacities (e.g. Tokyo);
- *Biodiversity syndrome* from stressing or over exploitation of biotic resources, introduction of invasive species, changes in the food web and regime change, (e.g. collapse of stocks of cod and tuna fisheries, jellyfish in Sea of Japan, *Mnemiopsis leidyi* in the Black Sea);

Table 1
Global change, according to Schellnhuber et al. (1997), and corresponding coastal change.

Global change	Coastal change
Composition of the atmosphere	The atmospheric deposition of pollutants and contaminants such as NOx, POPs and Hg, as well as ocean acidification due to increases in the partial pressure of carbon dioxide
Soil degradation	The degradation of the sea floor sediments by pollutants, anoxia, dredging and trawling, as well as the effect of dams and coastal structure on sediment fluxes
Loss of biodiversity	Loss of marine biodiversity such as top predators, as well as whole marine ecosystems based on corals, mangroves, seagrasses and kelp beds
Pollution of freshwater resources	Saline intrusion into coastal aquifers and their contamination by industry and agriculture, e.g. Yangtze (Changjiang) Delta
Allocthonous species, pests and disease	Invasion by non-indigenous species such as *Rapana venosa* in the Black Sea and *Caulerpa taxifolia* in the Mediterranean; loss of oysters due to *Perkinsus marinus;* sea lice (copepod) on salmon
Population growth, migration, megacities	Demographic movement to the coastal zone now inhabited by 45% of the world population and several megacities, as well as the seasonal migration to the coast by tourists
Affluence and sanitation	Informal settlements in the coastal zone of developing countries where basic human needs such as sanitation and clean water are lacking

- *Pollution and contamination syndrome* from industrial sources, agriculture and oil spills as well as underwater noise and marine litter;
- *Exploitation of non-renewable resources syndrome* such as oil and gas;
- *Global change syndrome* including increasing temperature, sea-level rise, storminess and ocean acidification.

A generic analytical framework showing the biophysical and institutional (human) components and critical interactions is useful to understand the coastal syndromes. Schellnhuber et al. (1997) provides a framework for the global syndrome, classifying them into three categories: utilization; development; sink. The list given by Schellnhuber et al. (1997) addresses the whole Earth System and so is more extensive than the list of coastal syndromes that has been proposed above. However, Table 2 shows how this framework can be applied to the coastal zone. Schellnhuber et al. (1997) also coupled some of the Global syndromes and this type of coupling also occurs in the coastal zone, as shown in Table 3. Fig. 2 shows a diagrammatic representation of common coastal syndromes. It is also possible to map some of the coastal syndromes on the corresponding river syndromes (Meybeck, 2003) and to relate these to ecosystem function and services in order to demonstrate how they impact on human welfare by affecting human society and the economy (see Table 4).

Coastal scientists are walking along a cliff-top in thick fog, not knowing where the edge is. It is therefore important to use the precautionary principle, since we are still unsure when coastal ecosystems reach thresholds and tipping points and then change in a non-linear manner (Duarte et al., 2009). Although we are navigating through a perfect storm of economic turbulence, mankind cannot consider environmental issues to be an expensive luxury. Coastal ecosystem goods, services and benefits continue to be misunderstood, undervalued and mismanaged, with externalities not accounted for. This takes us ever further from the sustainable use of the very ecosystems that we ultimately depend on for multiple benefits to our society.

A correct understanding of ecosystem services and their valuation can be very useful for decision-support, policy and management. These ecosystem services are often underestimated, especially when they do not have a “market” value (Brenner et al., 2010). This leads to marine systems being chronically undervalued (Kildow and McIlgorm, 2010). Nevertheless, payments for ecosystem service provision can be an effective approach at times (Kemkes et al., 2010). Day et al. (2009) eloquently argue that in an energy-scarce future, ecosystem services will become more important in supporting the human economy.

Coastal scientists are increasingly aware that many coastal zones are experiencing regime changes. Coastal ecosystem-based management (EBM) is further complicated by non-linear ecological functions and variables (Barbier et al., 2008; Koch et al., 2009). It is dangerous to raise expectations and the Duarte et al. (2009) paper is a cautionary tale about coping with regime change. Management measures are often insufficient to reverse the damage done to coastal ecosystem structure and function. The effect of global change on the coastal zone is difficult to quantify, but in many cases the degradation of the coastal systems seems to have passed a threshold and we may not be able to return to an

Table 2
Examples of coastal utilization, development and sink syndromes. Adapted from Schellnhuber et al. (1997).

Coastal Utilization Syndromes	
Overuse of marginal coastal lands	*Coastal land-use syndrome*: Development of coastal cities on marginal land, e.g. Dubai
Overuse of natural coastal ecosystems	*Decreased biodiversity syndrome*: collapse of the Grand Banks cod stocks; Atlantic tuna stocks; Oyster banks in Chesapeake bay;
Degradation of coastal zone through abandonment of traditional shellfish practices	*Decreased biodiversity syndrome*: clam dredging in Venice lagoon
Non-sustainable agro-industrial use of bodies of water	*Water syndrome*: Salinization and contamination of coastal aquifers, e.g. in the Mediterranean basin, and Baja California
Degradation through depletion of non-renewable resources	*Exploitation of non-renewable resources syndrome*: Offshore oil and gas exploration and extraction e.g. in the North Sea and the Gulf of Mexico
Development and destruction of coastal sites for recreational ends	*Coastal urbanization syndrome*: Mass tourism developments in the coastal zone e.g. Florida, Mediterranean
Environmental destruction through war and military action	*Pollution and contamination syndrome:* Deliberate oil contamination of the Arabian Gulf during the Iraq war with Kuwait; collapse of coastal tourism during the Balkan war after the fragmentation of Yugoslavia
Coastal development syndromes	
Damage of landscape by large scale projects	*Sediment syndrome and Water syndrome*: e.g. Shrinking of the Yangtze (Changjiang) Delta after the construction of 3 Gorges Dam
Degradation through the transfer and introduction of inappropriate aquaculture methods	*Biodiversity syndrome*: Unsustainable fish culture using feed pellets made from captured fish; *Coastal land-use syndrome*: destruction of mangroves for shrimp aquaculture ponds, e.g. Honduras and Indonesia
Disregard for environmental standards in the course of rapid economic growth	*Coastal urbanization syndrome* and *Pollution and contamination syndrome*: Coastal zones of rapidly developing countries e.g. the Guangzhou coastal zone of China
Socio-ecological degradation through uncontrolled urban growth	*Coastal urbanization syndrome*: Informal settlements (slums) without proper sanitation in coastal megacities (see Sekovski et al., 2012)
Destruction of landscapes through planned expansion of urban infrastructure	*Coastal urbanization syndrome* and *Coastal land-use syndrome*: Draining of wetlands for construction of infrastructures such as airports, e.g. Barcelona, Spain
Singular anthropogenic disasters with long term impacts	*Pollution and contamination syndrome*: Oil tanker accidents e.g. Exxon Valdez, Prestige, Erika; contamination of the Gulf of Mexico by the Deep Water Horizon accident; contamination of coastal water as a result of the tsunami flooding of the Fukushima plant in Japan
Coastal sink syndromes	
Environmental degradation through large-scale diffusion of long-lived substances	*Pollution and contamination syndrome*: Atmospheric transport of metals e.g. mercury and their deposition in marine waters such as in the Artic; atmospheric transport and deposition of POPs from coastal industry to coastal waters.
Environmental degradation through waste disposal	*Eutrophication syndrome*: Sewage sludge dumping at sea, e.g. New York Bight in the past, Urban Waste Water Treatment effluent; raw sewage disposal.
Local contamination of environmental assets at industrial locations	*Pollution and contamination syndrome*: Effluent and industrial waste water from coastal industries e.g. Porto Maghera Italy, Pearl River China, Aveiro Portugal, Huelva Spain

Table 3
Examples of coastal syndrome coupling based on Schellnhuber et al. (1997).

	Examples of coupling of coastal syndromes
Coincidence: occur at the same time in the same country or region but independently and without mutual reinforcements	Coastal urbanization and Pollution and contamination syndromes: e.g. in Spain. Mass tourism development and industrial development in the coastal zone
Coupling through common symptoms: two or more of the syndromes may share common key symptoms	Coastal urbanization and Water: e.g. Shanghai and salinization aquifer. Demographic growth is a shared symptom of both syndromes
Infection: one syndrome may trigger another	Coastal urbanization and Pollution and contamination syndromes: coastal zone industrialization increases pollution and contamination of the coastal waters, e.g. Pearl River
Reinforcement: symptoms or syndromes mutually reinforce each other	Rural marginalization and simultaneous urban growth, e.g. the influx of rural people into Asian coastal cities
Attenuation: the advent of one syndrome attenuates the effect of another	Schellnhuber et al. (1997) gives the example of the effect of the war in the former Yugoslavia on mass tourism, which can include coastal zone tourism
Succession: the historical development of an area leads to a succession of syndromes	Coastal areas that were previously degraded by activities such as dumping mine tailings are now developed for mass tourism, e.g. Mar Menor in Spain

unchanged *Neverland*. Ecosystem shifts in apparently similar systems may follow very different trajectories leading to the collapse or to the increase of a fishery (Yamamuro et al., 2006).

4. Hotspots on the coast

Hotspots on the coast are regions where many of the symptoms of coastal syndromes are experienced, often in synergy. As such, they correspond to the tipping elements mapped by Schellnhuber (2009). They are a result of the multi-stressors and usually combine both natural hazards, including those from climate change, and human vulnerability.

In the case of coastal natural hazards these include:

- Low lying areas, e.g. Bangladesh, Netherlands, Venice, Maldives, Micronesian islands;
- Subsidence areas, e.g. most large deltas, Po delta in Italy;
- Tropical Storm-surge belt, e.g. Caribbean, Gulf of Mexico, S.E. Asia; and
- Eroding coasts, e.g. Arctic permafrost coasts, N.E. England;
- and, a growing list of other examples.

In the case of human vulnerability on the coast, these include:

- Centers of population in a coastal floodplain, e.g. Bay of Bengal, Rio de la Plata/Parana, Nile;
- Coastal tourism-based economy, e.g. Thailand, Maldives, Algarve;

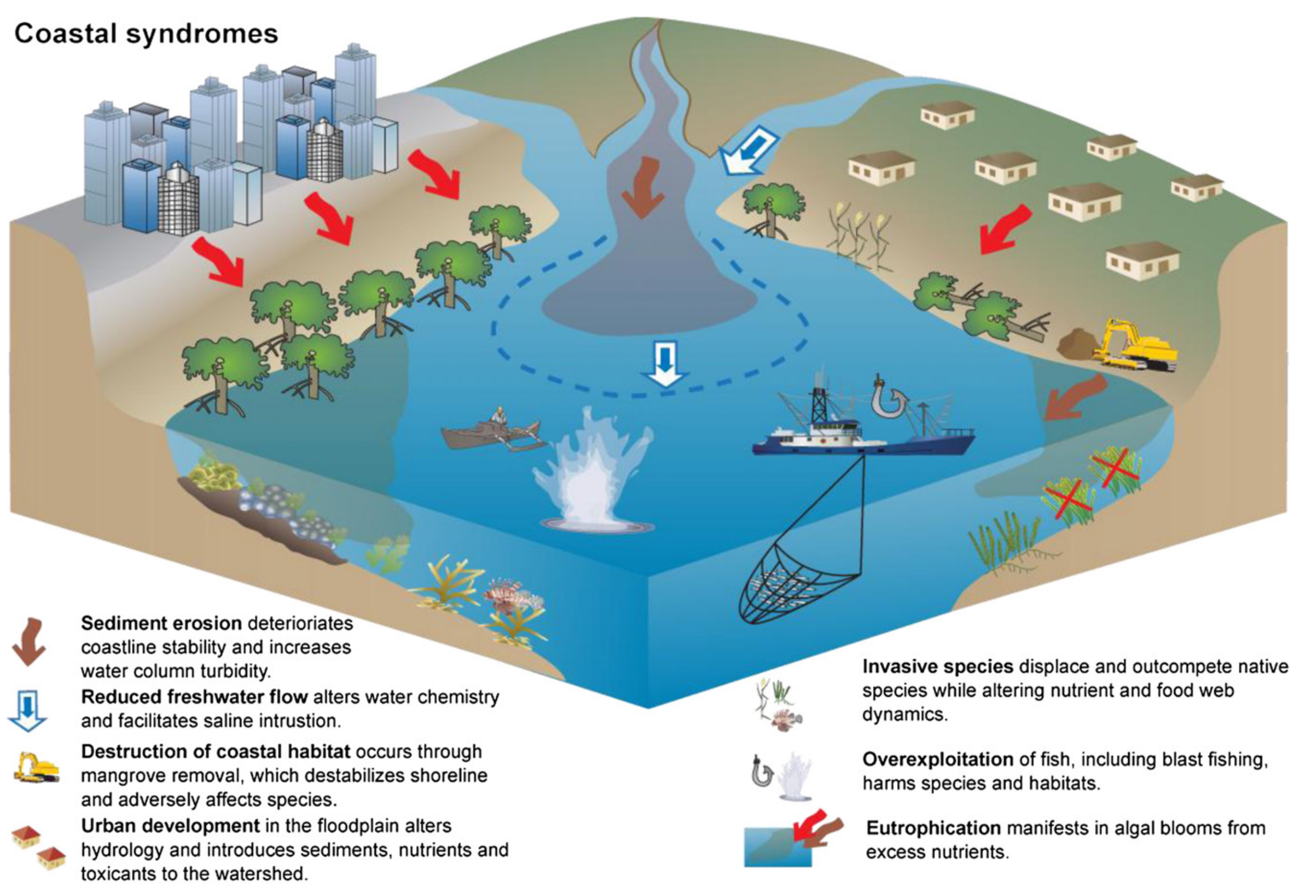

Fig. 2. Common global coastal syndromes.

Table 4
Coastal syndromes mapped onto the corresponding River syndromes and illustrating the impact on ecosystem function and ecosystem services, and effects.

River syndromes adapted from Meybeck (2003)	Coastal syndromes	Ecosystem function adapted from Granek et al. (2009)	Ecosystem services adapted from Granek et al. (2009)	Effects adapted from Nicholls et al. (2008)
Flood regulation, e.g. Changjian (Yangtze) Xu et al. (2005)	Global change syndrome: Sea-level rise and storminess Flood regulation e.g. Dutch coast	Wave and wind attenuation	Protection against storm surges and wind damage, Wamsley et al. (2010)	Inundation, flood and storm damage, erosion, defense failure, wetland loss (or change)
Sediment imbalance	Sediment Syndrome: Sediment imbalance e.g. coast of Mar del Plata	Sediment trapping Syvitski et al. (2005)	Shoreline stabilization and erosion control	HABs
Fragmentation of rivers, *dams*	Water syndrome and Sediment syndrome: Coastal structures e.g. groynes fragmenting coastal sedimentary cells, interrupting sediment transport and water flow	Silicate retention Laruelle et al. (2009)	Changes in food web dynamics	Decrease in commercial species, regime shift to "dead-end" species such as jellyfish Richardson et al. (2009)

- Traditional lifestyles, e.g. Arctic peoples;
- and, a growing list of other examples.

Fig. 3 shows a map of the global distribution of coastal hotspots.

4.1. River-mouth systems, hotspots of fluxes

Meybeck and Vorosmarty (2005) refer to hotspots of river fluxes and Halpern et al. (2009) identifies three hotspots adjacent to the Mississippi, Ganges, and Mekong rivers. According to van der Struijk and Kroeze (2010), the number of rivers with high N and P yields in South America will continue to rise to 2050 and this pressure will increase coastal eutrophication. This trend is not only restricted to South America but is a global trend, as shown by Seitzinger et al. (2010), and will also increase the probability of harmful algal blooms in coastal waters worldwide. In addition, many coastal aquifers in the coastal zone are contaminated by pollutants or fertilizers.

Many river-mouth systems are compromised because of freshwater retention and over-extraction as freshwater becomes increasingly scarce. Ranjan et al. (2009) evaluated coastal fresh groundwater resources on a global scale, within the context of global change, and highlighted the vulnerability of populous areas. But water extraction continues to rise endangering both freshwater-driven services and increasing the hazards for humans (Wagener et al., 2010). The over-extraction compounds the problems of sea-level rise and erosion by contributing to subsidence. Many of the major deltas are sinking thus endangering 500 million coastal inhabitants, worldwide (Syvitski et al., 2009).

4.2. Megacities in the coastal zone and urbanized coasts, hotspots of vulnerable populations

The different degree of development along coasts is also a challenge, ranging from small traditional villages on Pacific island coasts, such as Palau, to coastal megacities, such as Bangkok and Shanghai, where most of the coastal population is concentrated, often in informal settlements or slum conditions. The Coastal urbanization syndrome in its extreme form is a coastal megacity and is described in detail by Sekovski et al. (2012). Krass (2007)

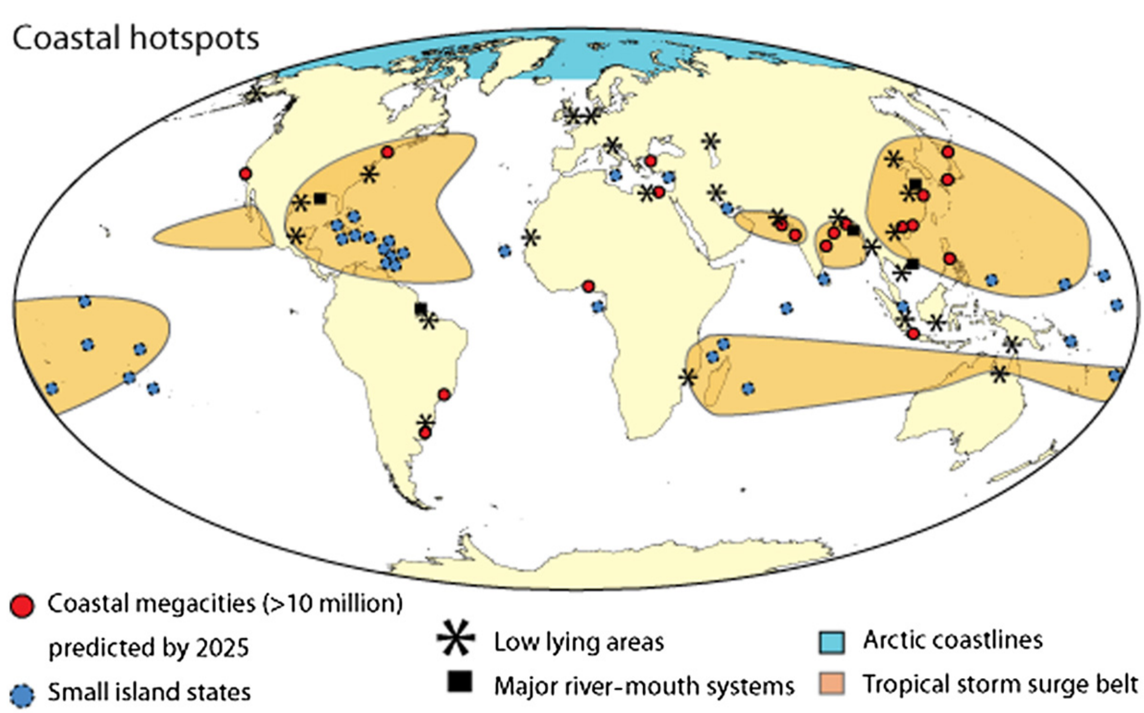

Fig. 3. Global distribution of major coastal hotspots.

identifies megacities as Hotspots of global change and these are also global risk areas (Krass, 2008). Although several megacities are coastal, many of them still lack adequate infrastructure such as urban waste water treatment. Coastal poverty is an inconvenient truth in many parts of the developing world and building sustainable coastal livelihoods in these regions is particularly difficult.

Asian mega-deltas and associated megacities are particularly impacted by environmental change and vulnerable (Woodroffe et al., 2006). The potential for disaster and large scale loss of life increases as the population of the coastal zone increases, even if there were no effects of climate change. In some areas, detailed studies of the possible effect of sea-level rise are being carried out (Heberger et al., 2009).

The role of the cities in global change is complex (Grimm et al., 2008) and it is important to have an appropriate set of urban indicators (Kötter and Friesecke, 2009). Emissions from these cities, (Gurjar et al., 2008; Joseph et al., 2009) contribute to climate change (Dodman, 2009). The cities also extract much groundwater (Hoque et al., 2007; Jago-On et al., 2009) causing changes in the sub-surface environment.

4.3. Arctic coasts, hotspots of climate change

The Arctic region has a circumpolar population of only 4,000,000 people, including Indigenous peoples' many of whom still lead traditional or semi-traditional lifestyles. Meanwhile, the Arctic Ocean is transforming from a frozen ocean to one that is seasonally ice free. Models indicate that rapid changes in the Arctic ice cover can be expected (Goosse et al., 2009), but may subsequently be followed by a partial recovery. However, ice-free summers are likely by 2060 (Holland et al., 2006). Climate change is revealing an Arctic coast that is made unstable by melting permafrost. Currently, the main coastal economic activities sustaining societies in the Arctic are fisheries, non-renewable natural resources both offshore and from mining, cargo shipping, and tourism (Glomsrod and Aslaksen, 2006). The Arctic economy has been limited by harsh environmental conditions and poor accessibility. But climate change will improve accessibility and the Arctic region will inevitably be further developed and exploited. New fishing grounds, new shipping lanes, Arctic Council, 2009, newly accessible resources on land and offshore (AMAP, 2007) and new destinations for tourists are already interesting entrepreneurs. As these activities increase, so will the pollution pressures on the Arctic coasts (AMAP, 2009). It is therefore crucial to ensure that proper governance structures are in place (Berkman, 2009; Young, 2009; Berkman and Young, 2009).

4.4. Island states and low lying areas, hotspots of sea-level rise

While the predicted sea-level rise from the IPPC (2007) report is rather conservative and does not seem alarming to the general public, it does not take into account local factors such as erosion, subsidence and storm surges, as well as vulnerability to tsunamis. The inhabitants of Hilo bay in Hawaii were impacted by several tsunamis before they rebuilding the town further back from the sea-front. But, on the Indian Ocean coast hit by the Banda Aceh tsunami, re-construction has often been on the beach front because this is the most desired space even though it is the most vulnerable.

IPCC (2007) also does not take into account catastrophic events such as the melting of the Antarctic ice-sheet (Bamber et al., 2009). It is therefore likely that the rate of sea-level rise may be greater than the current estimates (Grinsted et al., 2008). This makes many areas of the world vulnerable, but while the coasts of developed countries may be defended by expensive engineering works or managed realignment, there are fewer options for small island states in developing countries such as the Northern Cook Islands, Kiribati, Tokelau, Tuvalu, the Federated States of Micronesia and the Marshall Islands. Therefore, sea-level rise should not be the only consideration, when evaluating coastal vulnerability.

5. Responses of society and eco-innovation

There are many different societal responses to the coastal syndromes.

These include:

- Hard engineering, such as the construction of the Moses barrier for Venice;
- Managed realignment of coasts, allowing the sea to flood previously diked areas (Turner et al., 2007);
- Ecological and environmental engineering (Ferreira et al., 2009);
- Marine Spatial Planning;
- The creation of Marine Protected Areas (MPA's).

With respect to the eutrophication syndrome and nutrient runoff from agriculture, there has been some limited success to controlling phosphorus (Maguire et al., 2009; Harrison et al., 2010) but nitrogen continues to be a great problem (Rockstrom et al., 2010). Eco-innovation and novel approaches in ecological or environmental engineering are useful in certain locations, for example using bivalve aquaculture for the management of eutrophication (Ferreira et al., 2009; Nobre et al., 2009).

Coastal planning and Marine Spatial Planning are promising approaches to resolve the spatial conflicts of interest inherent in the coastal land-use syndrome. Technological tools such as GIS can be of great assistance in visualizing, understanding, communicating and solving coastal issues (Rodríguez et al., 2009). Multi-sectorial participation is essential but not always easy to achieve, as illustrated by McFadden et al. (2009) for the flood risk management of London. Nevertheless, participation is fundamental to build resilience in vulnerable coastal zones, such as the urbanized coast of the Netherlands, (Wardekker et al., 2010).

Another spatial solution is the creation of Marine Protected Areas (MPAs) and there are many very successful examples (Edgar et al., 2007). The EU has set up a network of Natura 2000 sites including many coastal areas. Nevertheless, MPAs need to be monitored for progress and to avoid developing problems. MPAs should also be coupled with integrated watershed management practices if fragile coastal ecosystems such as coral reefs are to be sustainable (Richmond et al., 2007). This is a partial solution to the Biodiversity coastal syndromes.

However, there are still many obstacles to progress in ICZM-Integrated Coastal Zone Management.

These include:

- The flow of information from science to inform policy makers;
- Short political cycles and long term investments;
- Mitigation and adaptation choices;
- Human behaviour.

The science-policy relationship is experiencing some difficulties and is hindered by obstacles and impasses. Unfortunately, a long term strategy is often of little interest to decision makers elected for short political terms. This can cause a miss-match between political will, length of electoral cycles and hysteresis that can cause problems in bridging research and policy. However, the investments are needed to secure the future of coastal inhabitants (Horstman et al., 2009). The Hartwell paper (Prins et al., 2010) underlines how the

Table 5
Activities in the catchment and the coast that have “human” consequences. Possible solutions arising from individual choice and societal responses are also shown.

Human activity in the catchment modified from Duarte et al., (2009)	Corresponding Human activity on the coast	Human consequences	Solutions at the individual level	Social and economic solutions
CO_2 emissions	CO_2 emissions	Flooding of low lying areas Collapse of agriculture	Hybrid or electric cars, LED lights, insulate home, microgeneration	Development of renewable energy e.g. wind farms, tidal and wave energy Geo-engineering
Over-extraction of freshwater, Damming rivers	Over-extraction of freshwater	Salination of aquifers. Water shortages, rationing, hose-pipe bans	No lawns, showers, low flush toilets	Drip irrigation, Pricing of water, desalination
Arable land, food production, excessive use of fertilizers	Caged fish aquaculture, fish meal	Increased price of wild seafood, loss of recreation and tourism, public health affected by algal toxins	Low meat and fish diet	Fertilizer limits, bivalve aquaculture
	Fishing ports and fish processing	Overfishing	Choose only sustainable seafood	Labeling of seafood, no catch times, areas. Regulating type of fishing
Occupation of the floodplain	Occupation of low lying coasts	Loss of property and loss of life	Choose not to live in low lying regions	Realign or protect Effective spatial planning High cost insurance
Destruction of riparian vegetation	Destruction of coastal vegetation	Loss of property from erosion and storms	Choose not to live in area	Realign or protect Effective spatial planning Replanting of vegetation

whole approach to the mitigation and adaptation to climate change may have to be reformulated. Inevitably part of the solution to coastal problems includes regulation. But how effective is regulation and how can we achieve compliance or is enforcement necessary? In which case, are the costs of policing and enforcing regulation reasonable and justified? Whatever the solution found to the problems of the coastal zone, there are inevitably some winners and losers (Langmead et al., 2007).

Desired coastal futures include natural space, source of renewable energies, industrial space, tourism and recreation space and transport space, most of which are mutually exclusive. In order to attain coastal sustainability, we need to understand and tap-in to human desires at the individual level, to achieve behavioral changes, and at the social level, to achieve demographic and governance goals. Environmental psychology may be a useful approach to interest individuals in making eco-friendly choices in their lifestyles (Marchand et al., 2010). But what works at one site is often difficult to apply in a different situation, and therefore an understanding of the local context is fundamental (Petheram and Campbell, 2010).

Table 5 summarizes some of the activities in the catchment and the coast that have “human” consequences. Possible solutions arising from individual choice and societal responses are also shown.

6. Conclusions

Coastal systems are complex adaptive systems (CAS) and present a particular challenge for governance (Duit and Galaz, 2008). Coastal management is often unsuccessful, despite attempts to apply ICZM principles (Billé, 2009). Similar failures have been documented for fisheries governance (Jentoft, 2007). An increase in the capacity for stewardship of oceans and coasts is needed if we are to attain the Holy Grail of sustainable coastal development (SCD) (Glavovic, 2006). Communicating scientific information to decision makers and coastal managers is important if Ecosystem Approach Management (EAM) is to be effective (Murawski, 2007). Building coastal partnerships that bring together interested stakeholders can be a very effective tool for governance to deliver local sustainability (Stojanovic and Barker, 2008). Scenario-based stakeholder engagement (SBSE) can be used to include stakeholder preference in decision making (Tompkins et al., 2008). But, ultimately the best, nested governance scheme from local to civic leader can fail because of spatial, temporal and budgetary constraints (Morris, 2008).

The syndrome approach provides a holistic view of related and interacting environmental issues, which may have related socioeconomic root causes and which may then be managed by addressing strategic nexuses within this network of interrelationships. This approach presents the decision makers and managers with an opportunity to examine such relationships for related or common causes and effects and to conceptualize strategic solutions that may address a suite of symptoms within the syndromes.

So, what are the conditions for success and what are the conditions for failure of introducing coastal management? The cure for coastal syndromes is not simple, but a key concept is adaptive learning in coastal planning, which has to increasingly conserve the valuable ecosystem services that healthy ecosystems can provide to coastal societies.

One of the conditions for success is the active involvement of all the actors:

- *the scientists*, including economists as well as natural and social scientists, who work together and not within the isolation of their disciplines;
- *the stakeholders*, including the relevant economic sectors, institutions, associations and NGOs;
- the *governance actors* such as policy makers, decision makers, local coastal managers and politicians;
- as well as an *informed and educated public*.

All of these actors have important roles to play in this coastal partnership. *The scientists* need to move from multidisciplinarity towards transdisciplinarity, but crucially scientists must seek to dialog with the other actors and not just with their peers, to identify the multi-stressors on the coastal system and to provide useful and necessary information to the stakeholders and decision makers. The scientists should be prepared to move from curiosity driven research to study the questions that are addressed to them by the other actors, if the science is to be relevant to the decision making processes and to curing the coastal syndromes. The *natural scientists*, using a System Approach, should provide a clear conceptualization of the coastal system and the linkages with the land and the ocean (land–ocean interactions in the coastal zone) within the context of global change and including the identification of the global change syndromes, (eg. SLR Sea-Level Rise). Most importantly they should identify the tipping points, when thresholds are reached and leads to ecosystem shift.

The *economists* should provide appropriate valuation of natural resources, ecosystem services and their benefits to society as well as cost benefit analysis to support decision makers. This should include the economic costing of externalities. The *social scientists* can provide great insights into the human dimensions of the syndromes and social constructs that could provide solutions. Crucially, the scientists should recognize the importance of an improved flow of knowledge based- scientific information to inform decision and policy makers and not just their peers.

Any coastal management plan to cure the coastal syndromes must include the engagement of the *stakeholder community*. For stakeholder engagement and participation to work it is crucial to use scenarios that are realistic for the stakeholders. All the relevant stakeholders should be included to enable deliberation and conflict resolution between the stakeholders, and therefore to minimize the winners and losers. The stakeholders, working with the scientists, can also better define what are the issues and problems causing the syndrome. For example, stakeholders may have a problem with water quality, but with the help of the scientists this can be further defined as the Eutrophication syndrome. This enables a better identification of the drivers and causes of the syndrome and the pressures exerted on the coastal system, including economic drivers and sectors, both local and global. The stakeholders must see clear benefits in the deliberation or they will rapidly lose interest and withdraw from the process.

The *Governance actors* require scientific knowledge to inform their decisions and to adopt the precautionary principle. They therefore need to engage in dialogue with scientists as well as with the stakeholders. Working with the scientists, the Governance actors can help to refine the research questions that will provide the appropriate context for the scientists. The Governance actors can also help to identify the changes in land use and changes in demography in the coastal zone. This is useful to better evaluate risk and vulnerability resulting from the key problems and issues affecting the coastal ecosystem and human social and economic welfare. A spatial approach can also enable the use of Coastal and Marine Spatial Planning and the designation of Marine Protected Areas as appropriate responses. However, the temporal aspects are even more important. Governance actors need to adopt a long term view, typically longer than electoral cycles, especially in the context of global change. The role of the *Informed Public* is crucial for this to be a success. Public education and public information enables the public to make informed choices, including electoral choices. An informed public is also better enabled to make appropriate lifestyle choices. 50 years ago, fuel consumption was not a major lifestyle criterion when purchasing a car. Correct information about marine products enables people to choose between eating sardines or tuna. The sum of more than 6 billion of these individual decisions can help towards the recovery and eventual cure of the coastal syndromes.

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