Adaptation to Climate Change in Coastal Areas of the ECA Region:

A contribution to the *Umbrella Report* on adaptation to climate change in ECA

Table of Contents

Index of Boxes

Executive Summary

Climate-related hazards are increasing in Europe and Central Asia (ECA), and geographical variations notwithstanding, most societies are faced with the need to adapt by trying to minimize negative impacts while seizing on the few positive effects.

Adaptation strategies aim at reducing vulnerability as a way to manage climatic uncertainty. Vulnerability is defined as a function of exposure to weather events, sensitivity and adaptive capacity; it varies significantly according to the magnitude of changes (which originate from the interaction between global and local climate patterns), and the characteristics of the system and sector affected. To reduce vulnerability, it is necessary to study the projected exposure and current levels of sensitivity and adaptive capacity of a specific region. This allows for understanding where interventions are necessary, which interventions can be implemented, and which are most likely to succeed.

The ECA region is at a stage where knowledge needs to be gathered on future changes, likely impacts and possible adaptation measures; the Umbrella Report has the specific goal to initiate this process and inform future analyses of climate change in ECA. The present section contributes by analyzing vulnerability and adaptive options of the coastal areas of ECA, with particular a focus on rising sea levels.

Coastal areas are particularly vulnerable because exposure to hazards comes both from the sea and from the land, and because of their high socioeconomic and naturalistic value. These hazards are not limited to climate change. The coasts of ECA may be particularly vulnerable as part of an economic system that is still struggling to complete the transition after the fall of the Soviet Union.

The basins under study, with the exception of the Arctic, are enclosed and as a result are going to be strongly influenced by changes in sea temperature and run-off. The synergy between these two factors and the already high nutrient loads especially characteristic of the Black, Baltic and Caspian Seas, threaten to increase the likelihood of eutrophication, algal blooms, and extension of hypoxic/anoxic zones, with consequent impacts on fisheries production, human health, and tourism. Run-off may increase in the Baltic and in the north of the Caspian (from the Volga) therefore flushing more nutrients and fostering extended eutrophication episodes. In the Mediterranean, Black, and Adriatic Seas, a decrease in total run-off is more likely, but this may still heighten the risk of eutrophication. In fact, during periods of drought or low-flow, pollutants are less likely to be flushed away, so when rainfall occurs it causes bursts of highly concentrated nutrients and pollutants that reach the sea.

Additional threats to human health and tourism may come as a result of the impacts of sea-level changes and increased storminess. Poor waste management practices in ECA have resulted in coastal pollution, worsened by the unregulated building of waste dumps and landfills. Shore erosion may increase the amount of pollutants and solid wastes flushed into the sea.

In the Caspian, where a drop in sea level is expected, the population may be encouraged to extend the development seaward; the result being increased exposure to heavy metals trapped at high concentrations in bottom sediments.

A few studies have analyzed the current sea-level-rise and storm conditions in ECA basins, including the Mediterranean and the Adriatic Sea, and projected the possible consequences of a one meter sea-level-rise. Erosion, floods, and infiltration of saltwater into aquifers already affect vulnerable lowland areas, river deltas, coastal wetlands and port cities. A one meter sea-level-rise would aggravate these problems, affecting for instance the alluvial plain of the Neretva in Croatia where land has been recovered for agricultural purposes, coastal protected wetlands in Estonia and in the Lena delta near the Arctic Sea, port cities in Turkey (including Istanbul), and along the Black Sea coast, Varna in Bulgaria and Rovinij, Pula, Split in Croatia. Vulnerability to these climatic changes is likely to be exacerbated by unregulated development in areas of the Arctic, and along the Albanian and Black Sea shores, including Bulgaria, Ukraine, and Georgia.

Overall, impacts are likely to be restricted to a limited number of sites along the coasts of ECA basins such that general vulnerability is considered low to medium. However, there is reason for concern, and it could be argued that vulnerability is higher when taking into consideration that in ECA there is a lack of awareness of climate change projections and impacts both at the Institutional and public levels, and that coastal development is accelerating, driven mainly by the tourism and energy sectors.

Because of poor understanding of the climate change threat, and because of the economic challenges faced by ECA countries, current ECA adaptive capacities are weak. In order to improve the situation, education and awareness of climate change must reach higher levels. Furthermore, it is necessary to analyze and improve the status of those technological, governance, and social aspects that contribute to adaptive capacity.

More research is also needed to consolidate the current knowledge of exposure and sensitivity of the natural and socioeconomic systems along the coasts. It is critical that coastal stakeholders across ECA are educated on the available adaptation options so they can tap into this expertise through the international community.

An Integrated Coastal Zone Management (ICZM) process could provide the framework to perform vulnerability assessments, guide awareness-raising, build adaptive capacity, and select the appropriate adaptation measures. It is suggested that ICZM would be the ideal instrument to manage adaptation to climate change events, and minimize human and material losses.

Typically, ICZM is a proactive process (but it can also be reactive and adjust goals along the way) that is often triggered by new developmental needs, new coastal threats, or the need to manage conflicts of interest between stakeholders.

Several of the coastal adaptation measures recommended by experts are part of an assortment of interventions ordinarily associated with ICZM. Generation and enforcement of zoning schemes, interventions to control erosion and the development of alternative employment are part of the ICZM arsenal; they can support adjustments in spatial planning (protect, accommodate, retreat) that are the center of coastal adaptation. ICZM can also promote strong ties between various sectors of the coastal communities and strengthen community organization. This, in combination with the promotion of awareness of climate change, is critical to the success of warning systems, another important piece of successful adaptation strategies.

Additionally, goals to empower local authorities and resolve conflict between coastal stakeholders address two of the main issues that most commonly undermine adaptive capacity.

In parallel to ICZM, Integrated River Basin Management (IRBM) has the characteristics to implement adaptation measures to control climate change events affecting coastal areas, by targeting issues along watersheds. An IRBM project can tackle river-planning water resources management and flood control measures to control the quantity, seasonal pulses, and quality of water reaching the coasts while taking into consideration the different uses and stakeholders' needs (agriculture, industry, urban needs).

In ECA, an IRBM to control emission from the Danube has met with good results. However, the rate of ICZM success to date is not very encouraging (SDN week 2008; World Bank 2003). Given these considerations, and the uncertainty of the projections, the interventions should be two pronged: (1) A process should be initiated to strengthen ICZM plans or kick start such projects where they are missing; (2) Local-scale projects should be implemented to address adaptation needs at a smaller scale; this is based on the idea that small positive outcomes may build consensus among Institutions and the public for the need of a wider approach managed through a general ICZM.

1. Introduction

1.1 Why coastal areas: definition and importance

The world's coastal areas represent only 20% of the available land but host between 40% and more than half of the global population (Burke *et al.* 2001). No single definition can encompass the complexity of coasts, and the demarcation of coastal boundaries is no easy matter, for coastal areas are complex systems composed by a range of terrestrial, intertidal, and marine environments with seaward and landward zones of influence that stretch far inland and out to sea. Different countries use different definitions and boundaries for coastal zones variably based on a combination of ecological, geographical, socioeconomic, historical, political, administrative, and legislative reasons[1]. While certainly informed by the ecological and geophysical characteristics of the coasts, these definitions are very much determined by functional and management requirements.

Coastal areas have been centers of human activity throughout history and current trends indicate that migration toward these zones is continuing. The main reason for this is that the rich variety of ecosystems and habitats in coastal zones provides a range of goods and services critical to human sustenance and well-being, particularly food production (e.g. fisheries and aquaculture), raw materials, and transportation options.

Coastal areas provide also other ecological and socioeconomic services with deep interrelations between them: erosion control of land and intertidal ecosystems (e.g. wetlands and salt marshes), storm protection, water purification, nutrient recycling, and recreation (tourism).

Due to their unique location, coastal areas are also at the receiving end of impacts coming both from the sea and from the land. This exposes coastal areas to the influences of climate change either directly (sea-level-rise, storm surges, floods, droughts) or indirectly through events that originate off-site but whose consequences propagate down to the coasts (river floods and changes in seasonality, pulses, quality of run-off).

This report will analyze coastal vulnerability to climate change, and possible adaptation options in four ECA basins: the Baltic Sea, the East Adriatic coast and Mediterranean coast of Turkey, the Black Sea, the Caspian Sea, and the Russian Arctic Ocean (Figure 1).

In terms of climate change impacts, the focus will be mainly on sea-level-rise (SLR), but comments will be provided on other hazards threatening the physical and socioeconomic dimensions of coastal areas.

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[1] Integrated Coastal Zone Management, "Coastal Zone: Concepts and Approaches, Gaim James Lunkapis, http://www.iczm.sabah.gov.my/Reports/Sandakan%201/mst-Coastal.html.

Figure 1 Map of ECA region. The basins under study are: Adriatic Sea (between Italy and the Balkans), Baltic Sea, Black Sea, Caspian Sea, and the Mediterranean coast of Turkey. Some notes will be provided also for the Arctic Ocean. Source: ref.

1.2 Importance of coastal areas in ECA

1.2.1 Social dimension of coastal areas

Coastal areas are most often defined through a combination of physical-geographical and management criteria. However, this presents difficulties when trying to assess the socioeconomic or biodiversity conservation value of coastal areas through the use of global data. To overcome this limitation, coastal areas are commonly defined as: "intertidal and subtidal areas on and above the continental shelf […] areas routinely inundated by saltwater, and adjacent land, within 100 km from the shoreline" (Martinez *et al.* 2007).

Using this definition, the social importance of the coastal areas in ECA basins is demonstrated by the percentage of population living within 100 kilometers of the coast (Figure 2 and Table 1). Albania and Estonia are small countries, which is why almost the entirety of their populations is included in this group.

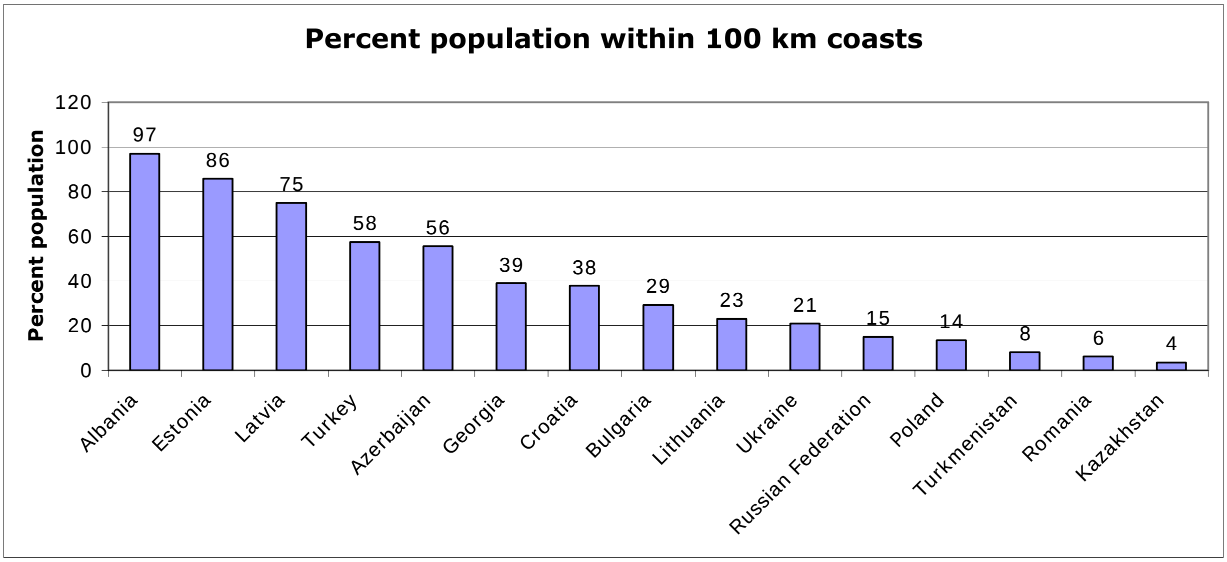


Figure 2 Percent of population living within 100 km from the coast. Twelve countries out of 15 have more than 10% of the total population located within 100 km of the coastline. Source: ref.

Table 1 Percentage of total population living within 100 km of coastline – average per basin

	Adriatic Sea[2]	**Baltic Sea**[3]	**Black Sea**[4]	**Caspian Sea**[5]
Average Population	68%	49%	28%	21%

[2] Includes Croatia and Albania
[3] Includes Estonia, Latvia, Lithuania, Poland
[4] Includes Bulgaria, Romania, Georgia, Ukraine, Russian Federation, Turkey
[5] Includes Azerbaijan, Turkmenistan, Kazakhstan, Russian Federation.
Source: ref.

1.2.2 The economic dimension of coastal areas in ECA

Establishing the relevance of coastal areas to the economy of a country is a more complex exercise. Fisheries do not constitute a great share of GDP in ECA basins. Fishery landings within a country EEZ[1] account for less than one percent of the GDP. Buys *et al.* (2007) examined a subgroup of ECA coastal countries and suggest that a SLR of one, two, or three meters would only affect between 0.13% and 1.99% of a country's GDP (Table 2). Georgia and Ukraine are predicted to be the worst off, followed by Estonia. Bulgaria and Romania are predicted to be the best off.

[1] EEZ: Exclusive Economic Zone. "Under the law of the sea, an Exclusive Economic Zone (EEZ) is a seazone over which a state has special rights over the exploration and use of marine resources" (*Wikipedia*, "Exclusive Economic Zone," http://en.wikipedia.org/wiki/EEZ.).

Table 2 Percent of GDP affected by a sea-level-rise of 1, 2, or 3 meters

	% GDP Affected		
	SLR (1 meter)	SLR (2 meter)	SLR (3 meter)
Estonia	1.3	1.42	1.53
Georgia	1.44	1.72	1.99
Poland	0.72	0.79	0.85
Romania	0.51	0.53	0.56
Ukraine	1.26	1.4	1.54
Turkey	0.7	0.9	1.1

Source: Buys *et al.* 2007.

The source study (Buys *et al.* 2007) has been object of criticism and this data may provide only a rough indication of the actual GDP affected. Firstly, model projections of sea-level-rise based on Intergovernmental Panel on Climate Change (IPCC) scenarios are between 0.09 and 0.88 meters by 2100; forecasts of two and three meters appear to be biased toward catastrophic previsions. Secondly, the study overlays sea-level-rise projections on a static socioeconomic system, and does not consider future development trends. This is a major shortcoming considering that coastal development is progressing quickly in ECA basins. Tourism is on the rise in the Mediterranean, Black, and Baltic Seas, and coastal tourism is expanding particularly in Ukraine, Russia, Romania, and Georgia. According to the World Tourism Organization (UNWTO) Turkey, Russia, Ukraine, Poland, and Croatia rank among the top 25 tourism destinations in the world.

Furthermore, these basins are the sites of important port cities (e.g. Constanza, Odessa, and Sevastopol in the Black Sea) and represent key routes for the shipping of oil and gas from Asia to Europe.

1.2.3 Natural capital of coastal areas

In addition to economic and social values, the fifteen coastal countries of the region are important from a biodiversity conservation standpoint (Table 3). Croatia, Albania and Turkey are part of the Mediterranean basin hotspot, and the entire Caucasus (including parts of Russia and Turkey) makes up the Caucasus hotspot.[2]

[2] Conservation International, "Biodiversity Hotspots," Conservation International, http://www.biodiversityhotspots.org.

Table 3 Number of Ramsar[3] sites and Marine and Littoral protected areas for the coastal ECA countries.

Countries	RAMSAR sites	Marine and Littoral Protected areas
Albania	3	7
Azerbaijan	2	3
Bulgaria	10	1
Croatia	4	18
Estonia	11	N/A
Georgia	2	2
Kazakhstan	1	1
Latvia	6	1
Lithuania	5	3
Poland	13	6
Romania	5	8
Russia	35	47
Turkey	12	14
Turkmenistan	N/A	N/A
Ukraine	33	17

Sources: Ramsar Sites Database; EarthTrends Searchable Database.

Figure 3 shows ecosystem service product (ESP) as a percentage of GDP. "ESP can be defined as the total value of ecosystem services and products of the different ecosystem types" in coastal areas (Martinez *et al.* 2007). This is an estimate of the "non-market" value for goods and services provided by the coasts: food, salt, minerals, oil, construction materials, shore protection against storms, cycling of nutrients, water purification, recreation, etc.

The very high number provided by Martinez *et al.* (2007) for the Russian Federation may be the result of several very important goods and services provided by the long coasts of Russia (37,653 kilometers): Arctic tundra controlling atmospheric CO_2, productive fisheries of the Barents and Bering Seas, numerous coastal wetlands providing storm protection, nutrient cycling and biodiversity conservation services, and raw materials provision.

[3] Ramsar is the international Convention on Wetlands (signed in Ramsar, Iran in 1971). "The Convention's mission is the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world" (Ramsar 2002).

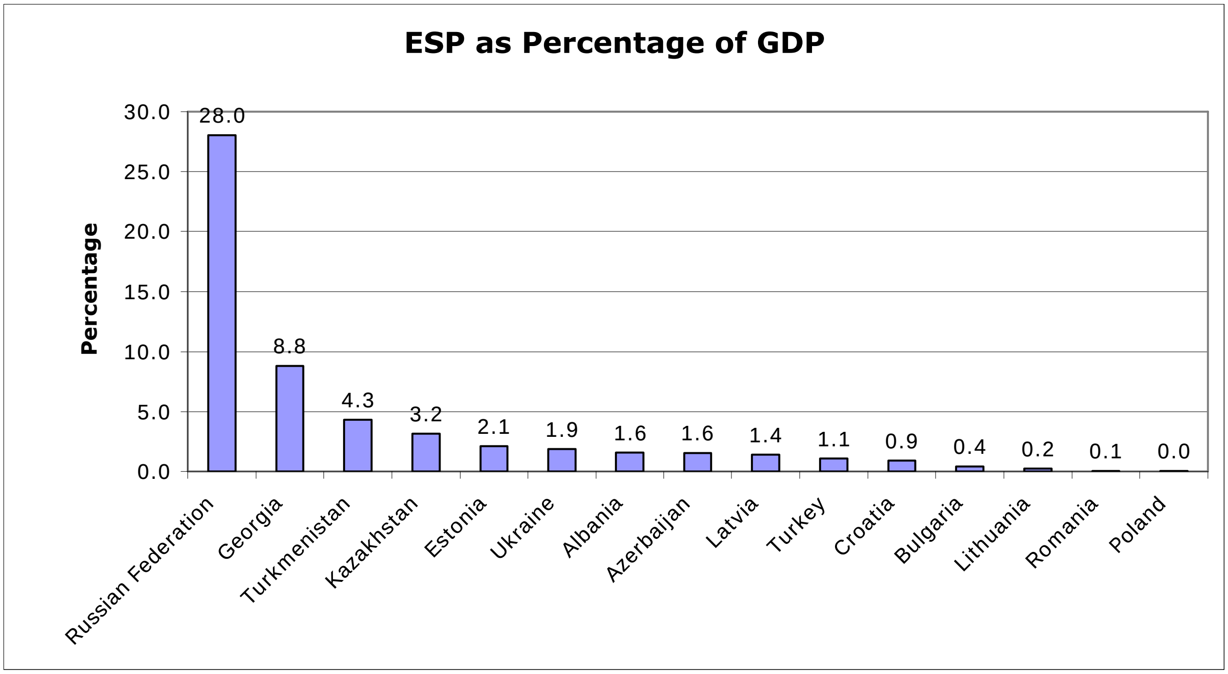


Figure 3 Ecosystem services product (ESP) as a percentage of national GDP. ESP represents the non-market value of ecosystem goods services delivered by the coastal zone.

1.3 Climate change in coastal areas

Climate change causes various impacts on ECA coastal areas through extreme weather events, long-term changing averages in climatic variables and increased weather variability (Table 4). Sudden severe phenomena such as storm surges, and gradual changes like SLR, will directly affect human well-being by damaging investments and infrastructures, and indirectly through modification of coastal ecosystems and habitats (Alcamo *et al.* 2007). Although climate change may offer positive opportunities as well as cause harm, it is expected that the latter will far outweigh the former. Furthermore, the IPCC reports that for the first decades of the 21st century some of these events will be heavily influenced by the North Atlantic Oscillation (NAO)[4].

According to several models these impacts would become most significant after 2050 (Alcamo *et al.* 2007). However, two aspects must be considered: (1) several observations indicate that climate change may be more dramatic than predicted (see glacier melt section), (2) coastal exposure to climate change can vary greatly according to interactions between global, regional, and local weather and biogeophysical factors. The rate of sea-level-rise is influenced by cyclical regional weather patterns, local atmospheric pressure, sea thermal expansion, coast subsidence, uplift caused by tectonic movements, and other hydrogeological factors (Nicholls *et al.* 2007; Nicholls and Klein). While the IPCC projects Special Report Emission Scenarios (SRES) indicatinh a global SLR of between

[4] The NAO is the air pressure gradient between Iceland and the Azores that influences the weather in northern and central Europe.

0.09 to 0.88 meters by 2100, in Europe the interaction with local factors may induce a SLR that could be 50% greater than the global estimates (Alcamo *et al.* 2007).

Given the uncertainty of current estimates, it is critical that an adaptation strategy be put into action in ECA. Adaptation to climate change in the context of coastal areas is defined as a policy process entailing decisions on policy and technological interventions that aim at reducing the vulnerability of the system to climatic changes. This section follows the general approach of the Umbrella Report in defining vulnerability as a function of exposure to climate change, sensitivity of the system, and adaptive capacity (Figure 4).

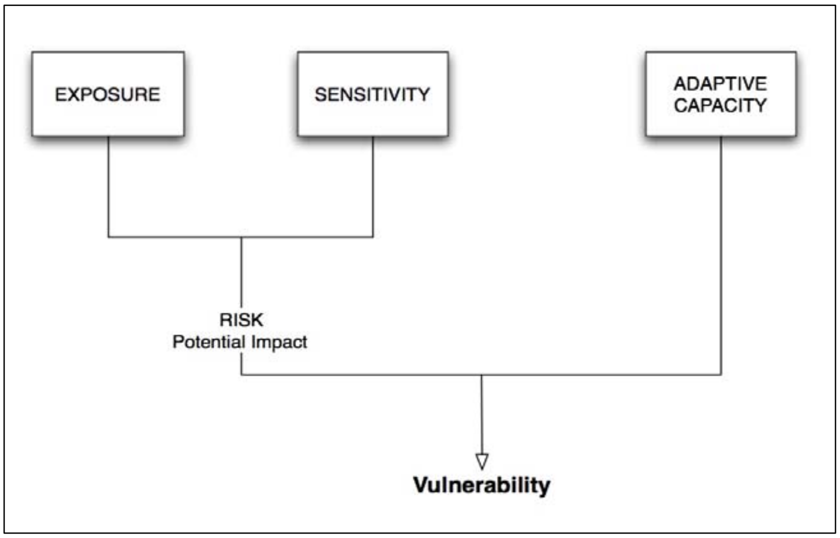


Figure 4 Vulnerability as a function of exposure, sensitivity, and adaptive capacity. Sources: Nicholls *et al.* 2007; Allen Consulting Group 2005.

In order to reduce the vulnerability of coastal areas to climate change it is therefore necessary to examine the exposure to climate change of the basins of interest, their sensitivity to the changes, the adaptive capacity (Box 1) and other factors that may influence these components. Some adaptation options can then be proposed to reduce vulnerability by reducing sensitivity to climate change and by promoting the development of adaptive capacity.

Table 4 Climate change events: induced changes and final impacts on coastal areas.

Projections	Changes 1	Changes 2	Effects on coastal resources
Increase in mean annual atmosphere temperature	• Less ice-cover on the sea • Thermal expansion • Less convection mixing	• Reduction of ice cover on the sea implies the wind will produce larger waves and there will be a higher incidence and strength of waves hitting the coast.	• Increased wave impacts imply a potential increase in erosion.[10] • Increased storminess responsible for most of flooding, erosion and destruction of infrastructure.
	• Increased storm intensity[11] in tropical and temperate waters	• Increased water levels and wave heights	• Increased coastal damage, coastal erosion, flooding affecting both natural and socioeconomic systems.
Increase in mean sea surface temperature	• Temperature may promote the spread of MSX, Dermo, and other diseases.	• Stress on fish immune systems	• Death and reduction of populations • Migration of organisms
	• Sea temperature and CO_2 concentration favor algal blooms in combination with increased nutrient run-off. • Sea temperature may exacerbate conditions of poor water oxygenation (lower solubility of O_2).	• Possible development of hypoxic and anoxic conditions • Higher temperatures may actually favor toxic algae (HELCOM 2007).	• Increase in temperature will impact fisheries and coastal production of goods: fish stocks may migrate, and benthos may die due to an extension of dead zones (eutrophication and oxygen depletion). • Impacts on biodiversity, fishery, aquaculture, human health, and tourism.
Sea-level-rise[12]		• Inundations • Erosion • Saltwater intrusion in aquifers • Increased salinization of rivers and bays	• Habitat loss (wetlands) • Reduction of light penetration may impact abundance and distribution of sea-grasses • Economic damages (losses of infrastructure, disruption of social systems) • Salinization of aquifers may impact drinking water and coastal agriculture. • Inundation of coastal landfills or other waste disposal sites • Disruption of urban drainage systems and wastewater treatment facilities

[10] The local sediment budget will determine the level of erosion, but in general sea-level-rise exacerbates erosion, more strongly on beaches and sandy shores, and less so in rocky coasts. The combined action of sediment starvation, sea-level-rise, and land subsidence may create conditions by which the water level rises too quickly for natural habitats to adapt and move inland. As a result, these habitats may be flooded and disappear.

[11] Storm intensity is predicted to increase both in tropical and non-tropical areas – this implies more coastal impacts than from sea-level-rise alone.

[12] Relative sea-level-rise, i.e. sea rise as a sum of global, regional, and local factors: global sea-level-rise + regional atmospheric and oceanic changes + thermal expansion + tectonic movements (uplift or subsidence) + human activities (groundwater abstraction)

Projections	Changes 1	Changes 2	Effects on coastal resources
Storm surges + Sea-level-rise	• Storms will "ride" on a higher sea level, hence the vulnerability of coasts will be higher (Scavia *et al.* 2002). • Synergy between the two		• Erosion and more damages to coastal systems • Permanent changes in coastal forests due to coastal storms are more dramatic where infiltration of seawater already caused some impacts, by reducing the regenerative capacity of tree stands species (Williams *et al.* 2003)
Increased CO_2 concentration	• Acidification of sea water (-0.1 pH units since 1750)[13]		• Reduction of marine invertebrates growth and survivorship (Harley *et al.* 2006)
Droughts or extreme rainfall events in upland regions	• Altered run-off - altered quantity and seasonality of pulses of water and sediments (this also influences the quality of water)	• Changes in water salinity, turbidity, temperature • Disruption of microbiological activity • Disruption of life cycles of flora and fauna	○ Impacts on human health and tourism ○ Impacts on biodiversity (including phytoplankton and other primary producers) ○ Impacts on fisheries and aquaculture (Scavia *et al.* 2002)
	• Decreased run-off (lower freshwater delivery) increases water residence time.	• Increased salinity, modified stratification, and mixing • Higher residence time of phytoplankton means higher susceptibility to eutrophication (Scavia *et al.* 2002).	• Eutrophication and hypoxic conditions (also exacerbated by higher sea temperature) • Other impacts on biota due to changes in water salinity
	• Floods		○ Impacts on both natural and socioeconomic systems

[13] In theory acidification should be stronger in colder seas because CO_2 solubility in water is higher at low temperatures.

Box 1 The elements of vulnerability in coastal areas

Exposure

Exposure refers to the natural hazards affecting coastal areas. The hazards belong mainly to three broad categories:

1. Discrete hazards (also referred to as extreme events)
    a. Storm surges
    b. Extreme rainfall events or droughts in upstream terrestrial areas
2. Continuous hazards (changing averages)
    a. Sea-level-rise
    b. Gradual increase in air and water temperature
    c. Acidification of seawater
3. Increased weather variability, in terms of storm seasonality, frequency, and intensity, and changes in run-off quantity and seasonality.

Sensitivity[14]

The biophysical and socioeconomic properties of a system are the *determinants* of sensitivity of the system to climate change, and determine the magnitude of the outcome (impact) of a physical hazard (Brooks *et al.* 2005).

- Generic determinants*:* mediate sensitivity to a broad range of hazards including non-climatic ones (e.g. poverty and inequality levels or the general health of the population apply to coastal areas as well as to other systems and range of hazards.
- Specific determinants: mediate sensitivity for particular hazard types. For instance, the topography of a coast is a determinant specific for the sensitivity to sea-level-rise and storm surges; given a magnitude of exposure, a particular cliff height might result in a low or high sensitivity of the coast to that hazard. This is intuitive, as a higher cliff provides more protection to human settlements. Another example is the quality of housing; this can be a determinant specific for sensitivity to floods and windstorms (Brooks *et al.* 2003).

Adaptive capacity

The UK Climate Impact Programme (2003) defines adaptive capacity as "the ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptation can be spontaneous or planned, and can be carried out in response or in anticipation of changes in climatic conditions." Adaptive capacity is therefore a combination between the availability of policy and technological adaptation options, and how fast they can be implemented. Adaptive capacity can be both at the country and local levels: quality of corruption control and effectiveness of regulatory environment, access to health care, education and information, and presence of social networks.

It is important to stress the difference between sensitivity and adaptive capacity. For instance, coastal population density is a property of the system and as such mediates the impact of a hazard. On the other hand, the level of expenditure for coastal protection structures is a way to reduce the threat and as such is part of adaptive capacity.

[14] This is the basic definition of sensitivity, prior to any adaptation measure and without considering the actual adaptive capacity of the system.

1.4 Exposure and sensitivity to hazards in coastal areas

Coastal areas are complex environments where natural and socioeconomic systems are deeply intertwined. Therefore, before investigating exposure, sensitivity and adaptive capacity in the ECA region, it is necessary to clarify how these definitions apply to the specific context of coastal areas.

Table 5 focuses on the different coastal dimensions of exposure and sensitivity. Proceeding from left to right, the climatic hazards initially affect the natural system and the magnitude of floods, erosion, etc. (Outcome I) are mediated by the sensitivity of this system. For instance, the magnitude of erosion caused by sea-level-rise depends on geological features of the coasts, in particular on the relief and geology (beaches versus rocky reefs). Similarly, the extent of flooding caused by extreme rainfall events in the upstream catchments is mediated by the state of the basin, its hydrogeological characteristics and water resources in the aquifer.

The biogeophysical events triggered by climate change hazards, and mediated by the sensitivity of the natural system (first level sensitivity) affect a range of natural and socioeconomic coastal sectors. The magnitude of the impacts on the socioeconomic system (Outcome II) depends both on the type and the magnitude of the hazards hitting the system (the Outcome I) and on its second level sensitivity. The latter is often calculated based on the social and economic importance of coasts as measured by a range of indicators: population density, economic importance of fishery activities, and industries like tourism and shipping. The division in sectors helps to identify all the activities and elements that could be affected by hazards.

Extreme events, sea-level-rise, and changes in precipitation all cause second level outcomes (Outcome II) that include damages to housing, industrial, and transport infrastructure. Human health can be affected due to damages to water treatment systems and waste disposal sites. Also, ecosystems can be damaged; sea storms may impact wetlands as saltwater infiltration into aquifers has been proven to reduce resilience of coastal forests to storms. Increases in sea temperature and acidification impact flora and fauna directly, causing consequences for biodiversity, fisheries, and aquaculture. All these outcomes are summarized in Table 5.

Table 5 Coastal dimensions of exposure and sensitivity to climate change events: from exposure to hazards to outcomes.

Climate Change Events – Exposure to Hazards	**1st Level Sensitivity Determinants** **(this determines for instance the extent of flooding – outcome I)**	**Outcome I** **Biogeophysical Impacts**	**Sectors Exposed to Outcome I**	**2nd Level Sensitivity Determinants**	**Outcome II** **Impacts on socioeconomic system**
1. Extreme events – storms 2. Sea-level-rise	• Biogeological features of the coasts o Relief o Geology o Coastal landform o Coastal retreat o Tidal range	• Erosion • Beach migration • Coastal dune destabilization • Flood (from upstream watershed) • Changes in run-off due to upstream extreme rainfall events or droughts • Inundation (storms and sea-level-rise) • Saltwater intrusion	• Ecological systems o Biodiversity • Economy o Ag-forestry o Fisheries o Aquaculture o Industry (e.g. tourism) • Infrastructure o Ports shipping o Housing o Roads o Water sector o Energy sector • Health	• Population density • Number of marine/coastal protected areas • Fishery and aquaculture % of national GDP • Revenues from tourism as % of GDP • Historic/cultural importance	• Loss of lives • Loss of property • Damage to infrastructures • Increased risk of diseases Economic losses: damages to agriculture, fisheries etc • Loss of cultural resources • Forced migration • Loss of ecosystem goods and services
3. Heavy extreme rainfall events in upstream terrestrial areas 4. Droughts in upstream terrestrial areas	• State of the water basin o Physicogeographical and hydrogeological features catchment o Amount of lake or groundwater storage				
5. Sea temperature rise 6. Sea water acidification	• Modeling takes into consideration necessary parameters.				• Direct changes to sea: impacts on biodiversity, and fisheries

Key: White cells represent the exposure and sensitivity of the natural systems. Yellow cells represent the socioeconomic system.

2. Exposure and sensitivity in ECA coastal lines

This section presents some details of exposure and sensitivity to climate change for coastal areas of the basins of interest (Baltic Sea, Black Sea, Adriatic and Mediterranean Seas, Caspian Sea, and Arctic Ocean). Specific examples illustrate how hazards from sea-level-rise and storm surges result from a combination of global trends and local conditions, including tectonic uplift or subsidence of the coasts, local weather and pressure systems, changes in river run-off and evaporation patterns. As it was not possible to obtain original modeling projections for SLR, data was collected from different literature sources analyzing different scenarios and time horizons. An effort has been made to be explicit on the source and the scenarios utilized.

In addition, some cases will be presented to describe possible synergies between climatic changes and other stressors currently affecting ECA marine basins. This is important as it must be recognized that vulnerability to climate change of both natural and socioeconomic sectors of coastal areas will depend not only on changes in climate, but also on the interaction between these and stresses like pollution, overfishing, land use change, and habitat fragmentation, along with population increase and changes in governance, economics and cultural values. These external factors affect vulnerability by impacting either the sensitivity or the adaptive capacity of the coastal area systems make (Figure 5).

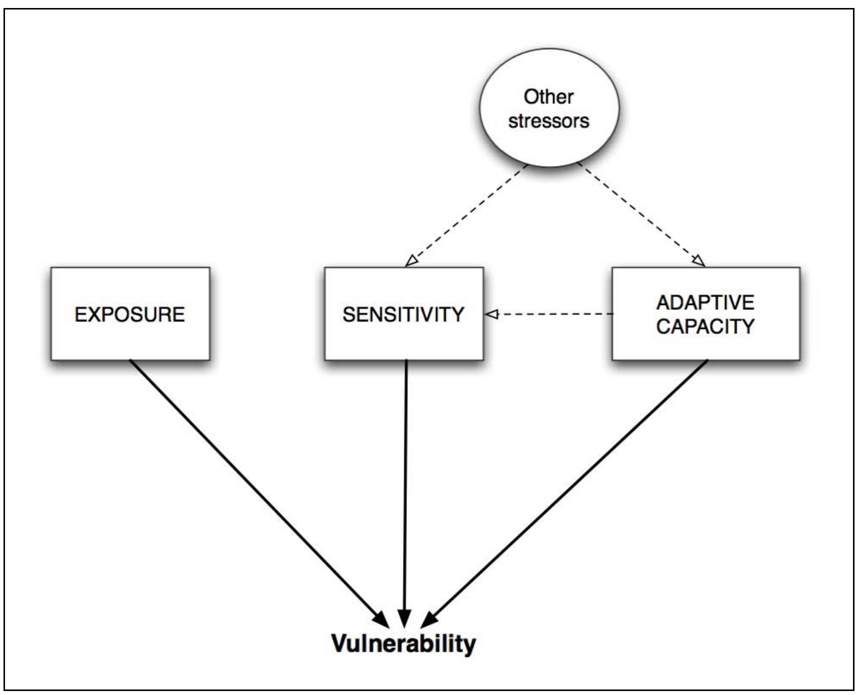


Figure 5 External stressors including societal and governance changes, along with environmental impacts such as pollution and overfishing affect the vulnerability of coasts to climatic changes by affecting the sensitivity and adaptive capacity of coastal systems.

2.1 Baltic Sea

2.1.1 Weather observations in the 20th century

The Baltic is an area of great weather variation, daily and annually, mainly correlated with the patterns and strength of the North Atlantic Oscillation (NAO). However, in the last few decades some climatic trends have been detected, which do not match with the patterns of NAO, and are therefore consistent with a changing climate.

Regarding long-term gradual changes, a warming trend has been registered in the Baltic greater than the global averages, 0.08 °C increase per decade versus 0.05 C globally (HELCOM 2007). The overall results in the basin have been an increase in the growing season and in the length of the frost-free season; the ice season (the period of the year when ice covers the sea) has been reduced to between 14 and 44 days in the 20th century (HELCOM 2007). In rivers and lakes, ice thickness has decreased by up to twenty percent in the past 40 to 50 years, and the duration of river ice coverage has shortened to/by 25 to 30 days in the north and 35 to 40 days in the south. Also, between 1990 and 2005, annual sea surface temperature has increased up to 0.8 °C in some areas (HELCOM 2007).

An increase in precipitation has been reported, mainly restricted to the northern part of the Baltic, while the south has experienced a decrease in precipitation. The increase in precipitation in the northern areas has overshadowed the general increase in temperature and caused an increase in snow cover. Conversely, in the last 50 to 70 years, the mean snow cover duration in the south has decreased in Estonia, Latvia, and Lithuania[13].

No significant trend has been noticed in the past century for what concerns extreme wind episodes. These are relevant for storm surges, and flooding, and therefore impacts on coastal areas, but the collected data is consistent with NAO-generated events.

2.1.2 Climate change projections

Projections for the Baltic presented in the climate science section of this Umbrella Report show an increase in mean annual temperatures, with greater warming in the winter with respect to the summer. Increases in winter precipitation, decreases in frost days, and longer heat-waves are also predicted, and will lead to less sea-ice cover. Run-off will vary between different regions and projections forecast an overall small increase in run-off for the Baltic (HELCOM 2007).

The Baltic Marine Environment Protection Commission (HELCOM) has produced a study (2007) on projections of climate change variables using global and regional GCM (global circulation models) based on four different Special Report Emission Scenarios (B1, B2, A2 and A1Fl) using 2100 as time horizon. In summary, the study estimates that the warming in the Baltic will exceed the global mean warming up to 50% (mean

[13]Snow accounts for large proportions of run-off and is a major factor in flooding, so this may mean better conditions in the south

atmospheric annual to increase of 3 to 5 °C). The northern areas should experience the largest warming in winter-spring, and the south should comparatively warm up less, and mainly in the summer months.

Due to the temperature increases the snow season will reduce further. Also, the sea-ice season will shorten, decreasing dramatically both in the north (1 to 2 months less) and in the central Baltic Sea (2 to 3 months less) (HELCOM 2007). The increase in sea temperature (strongest in the central and south Baltic) and the reduced ice cover (-50 to -80 % by end of 21st century) are expected to further increase storminess and enhance coastal erosion (HELCOM 2007). These impacts are presented in Table 4.

Regarding the hydrological conditions the HELCOM (2007) predictions are:

1. Increased mean annual river flow in northern catchments
2. Decreased mean annual river flow in southern catchments
3. Decreased summer river flows
4. Increased winter flows by 50%.

Hydrological conditions vary regionally and locally. Temperature increases influence snow volumes along with geological features, evaporation, and changes in precipitation. These conditions then alter the timing and volume of run-offs.

Sea-level-rise conditions are expected to depend mostly on a combination between global sea-level-rise, the "uplift of the Scandinavian plate" on the north, and the lowering of the southern Baltic coasts. Taking these factors in consideration, a sea-level-rise of 1.7 millimeters per year has been recorded in the southeastern Baltic, while a decrease in sea level of 9.4mm per year is reported for the Gulf of Bothnia between Finland and Sweden (HELCOM 2007).

SLR may increase coastal erosion particularly in the south (i.e. Poland). And an increase in windiness as projected through several GCMs could further increase these impacts but the current forecasts have high levels of uncertainty, and the magnitude of climate change impacts cannot be ascertained above natural variability as yet.

2.1.3 Examples from Baltic: Estonia and Poland

The best studies on coastal vulnerabilities to SLR in the Baltic have been carried out in Estonia and Poland.

Estonia

The effects of climate change, in particular sea-level-rise and increased storminess, have been studied in seven different sites, covering the most characteristic Estonian coastal areas (Kont *et al.* 2008; Kont *et al.* 2003).

The low-lying and mostly sandy coast of Estonia is highly sensitive to sea-level-rise, flooding, and erosion. Historically, the Estonian sea level has fluctuated due to changes in precipitation, river discharge, and storm patterns, but to date no obvious trend of sea-level-rise has been recorded. This may be due to a combination of local weather conditions and to tectonic uplift, that in the area is between 1 and 2.8 millimeters per year (Kont *et al.* 2008).[14] Despite this, in the past decades erosion rates on sandy beaches have increased, probably as a result of increased storminess linked to sea warming and to the reduction of sea-ice cover, particularly during the winter.

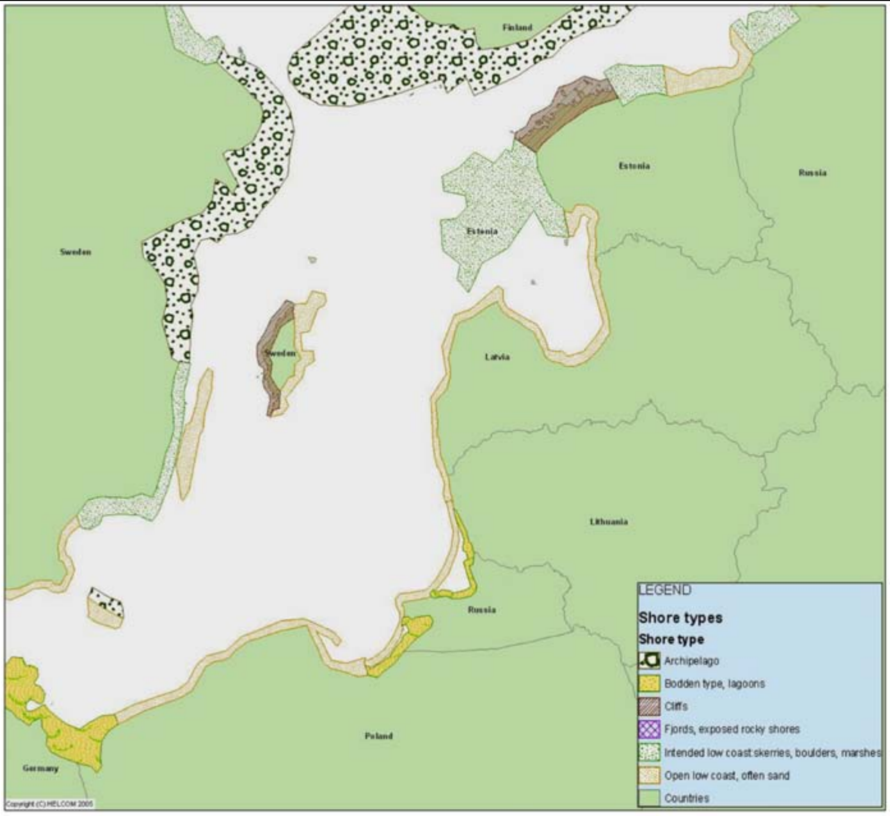
The geological characteristics of the coast (Figure 6a), and the low relief makes the natural system of Estonia particularly sensitive to storms, consequent flooding, and erosion. Kont *et al.* (2003) assessed vulnerability of Estonian coasts in terms of natural and socioeconomic systems, considering a one meter global SLR taking place between 1990 and 2100.

Taking into land uplift consideration, the western shores (including the Hiiumaa island) would be exposed to wetland inundation, extensive flooding leading to loss of reed beds, coastal meadows, lagoon ecosystems, spawning trout grounds, and breeding grounds of migratory birds, including grouse (Figure 6b). The Matsalu bay (the bay depicted in green at the center of the western Estonian coasts, Figure 6b) is home to Ramsar sites and important bird areas, and it would be particularly impacted by flooding and storm events.

Differently from most of Europe, the Estonian coasts are scantily populated and, with the exception of few harbors, coastal settlements are on higher elevations and further inland. Therefore, the sensitivity of the socioeconomic system is presently very low, and moderate SLR does not represent a threat. The only two vulnerable sites are the city of Tallinn (the capital of Estonia) and the Sillamae industrial center. The latter is the dumping site for radioactive wastes of a former uranium enrichment plant. These wastes regularly leach into the soil and water and are separated from the sea by a narrow dam. Increased storminess and sea-level-rise could result in a massive quantity of radioactive material being flushed directly into the Baltic. The city of Tallinn is one third protected by seawalls and groins, but the defense system will require adjustments due to the increased storminess. In general it seems unlikely that climate change will bring great harm to Estonian coasts; however, the conditions may change in the future as the country is registering an increased interest for coastal development, partly for tourism purposes.

a

[14] Measures of tectonic uplift and net seal-level-rise are site specific. This explains the differences in level reported across this section on the Baltic Sea.



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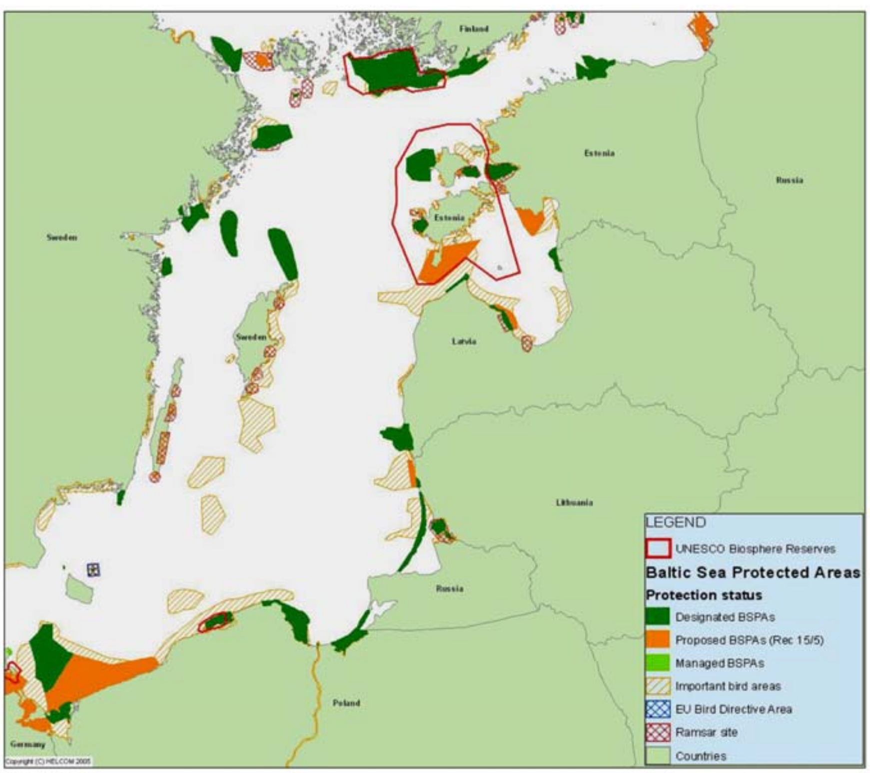


Figure 6 a Baltic coast typology. Estonia has low coasts especially in **b**, areas of Baltic biodiversity interest. Source: HELCOM GIS.

Poland

Studies based on GCM models have predicted an increase in temperature for Poland, along with increased frequency and strength of storm conditions (Pruszak and Zawadzka 2008). Measurements begun in the 19th century also show a trend of increasing sea level through a combination of global SLR forecasts and local observations; Poland coasts are projected to see an increase in sea level of 45 to 65 centimeters by 2100 (Pruszak and Zawadzka 2008).

Poland's coasts are low-lying and mostly sandy (Figure 6a) and they are historically exposed to flooding and erosion (coastal defenses have been built since the 19th century). These events have been increasing since the 1970s as a result of sea-level-rise, increased storminess and sediment starvation caused by regimentation of rivers.[15] Pruszak and Zawadska (2008) point out that the socioeconomic vulnerability of the coasts (without considering adaptive measures) is particularly high at the eastern and western extremities of the Polish coast. The cities of Gdansk, Gdynia, and Szczecin are of particular industrial, economic, and social importance and are in proximity to the main areas of flooding: the lagoons and lowlands of the Odra and Vistula deltas (Figure 7). Sensitivity could increase as coastal development is on the rise since the 1990s, following growth in national GDP.

The ports of Swingujscie and Ustka are of national importance and are also in sensitive areas. However, the central regions of the Polish coast ecosystems are the most vulnerable to flooding, and include lagoons, important bird areas, and a UNESCO biosphere reserve (Figure 6b).

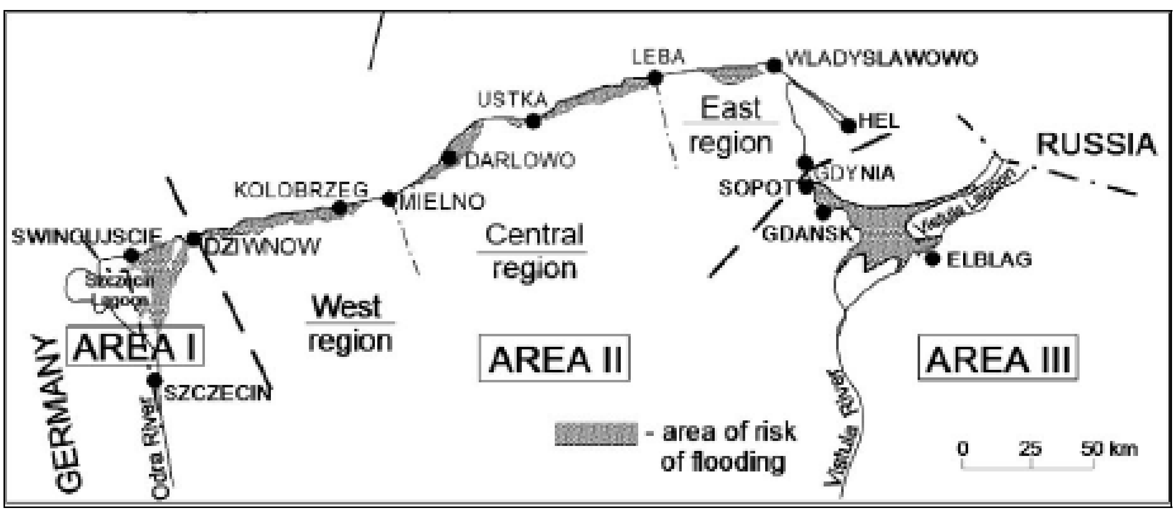


Figure 7 Areas at risk of flooding on the Baltic coasts of Poland. The Odra River to the east scores the border with Germany. The Russian border is at the top right corner of the map. Source: Pruszak and Zawadska 2008.

[15] Subsidence has little effect, being only of 1 mm/year

2.1.4 Synergies between climate change and current stresses in the Baltic Sea: eutrophication & human health

Eutrophication[16] is a serious issue in the Baltic Sea. It is caused by the discharge of nutrients and sediments collected along the vast river basins feeding into the sea, and it is worsened by the slow water exchange with the North Sea. Extensive blooms of algae and cyanobacteria have been reported in the since the 19th century, but in the last decades they have increased in duration, frequency, and biomass (Bianchi *et al.* 2000).

Run-off into Baltic Sea is predicted to increase over this century due to enhanced precipitations related to climate change (HELCOM 2007). ECA countries in the south of the Baltic basin are likely to be exposed to a higher risk of flooding which will contribute to leaching of nutrients into the sea. Because run-off accounts for up to 97% of the nutrient influxes from the land to the sea in the Baltic area, it is assumed that increased run-off will translate into a greater input of nutrients, and possibly exacerbate eutrophication events (HELCOM 2007).

In addition, surface sea water in the Baltic has been warming for the past fifteen years and the trend is projected to continue (HELCOM 2007, Alcamo *et al.* 2007). Assuming a concurrent increase in nutrients, the combination of these two factors may result in enhanced phytoplankton growth. An increase in frequency and intensity of these events raises concern as several species of cyanobacteria carry toxins harmful to human and animal health.

Warming may exert selective pressure limiting the growth of cold-water species like diatoms while favoring warm water species like the toxic *Nodularia*. In fact, the growth of diatom and dinoflagellate species is optimal only at temperatures just above freezing, while blooms of cyanobacteria occur only at temperatures higher than 16 ºC. Furthermore, temperature increase has an enhancing effect on cyanobacteria regardless of run-off nutrient inputs. This is partly due to the fact that cyanobacteria can naturally fix nitrogen and therefore contribute directly to eutrophication (HELCOM 2007).

Nodularia spumigena produces toxins called nodularins. These have hepatotoxic effects causing gastrointestinal illnesses and liver damage in case of persistent exposure (Hallegraeff *et al.* 2003). Acute toxicity is the most direct threat, but short, chronic exposures could lead to serious health effects. For instance it is hypothesized that "cyanobacterial toxins are part of a complex of risk factors" that determine the high incidence of human hepatocellular carcinoma registered in China (WHO 1999).

Cases have been reported of death of cattle and pets after ingestion of water or scum containing *Nodularia* (WHO 2003) , and although there are no reported cases of human

[16] Eutrophication literally indicates an over-nourishment. The term is used commonly to refer either to out of norm algal blooms, or to the massive death of organisms following the decomposition of algae and the loss of oxygen in the water. The trigger of these events is the availability of enormous quantities of nutrients both inorganic and organic.

poisoning to date, the possible increase of *Nodularia* blooms represents a hazard for human health. The risk of exposure could be particularly high for children (WHO 2003).

2.2 Caspian Sea

The Caspian Sea is the largest enclosed water body. It is a 1,200 kilometer–long brackish basin, and because of its north-south orientation it is subject to a variety of climatic conditions, from a continental climate on the northern shores to sub-tropic conditions in the south. In winter, sea temperatures in the north are close to 0 ºC, with large expansions of water covered in ice. In the south, temperatures are around 10 ºC.

Fluctuations in sea level have been one of the most defining characteristics of the Caspian, and they depend on both natural and human-induced factors. The Volga provides 80% of the total water inflow to the Caspian, and the outflow is mainly determined by surface evaporation. Changes in river flows and in climate temperature modify inflow and outflow, hence causing most of the sea level change. Human activities, such as damming and water abstraction, have a smaller impact.

Climate change is likely to modify the hydrological budget[17] of the Caspian Sea, and induce variations in sea-level-rise through increased inflow from the Volga and enhanced surface evaporation from the sea itself.

Recent studies (Renssen *et al.* 2007; Elguindi and Giorgi 2007) have projected sea level change in the Caspian using climate models based on the IPCC A1B scenario for the 21st century. Incidentally, this is the scenario adopted for this Umbrella study on climate change in ECA (see climate science section).

The model used by Renssen *et al.* (2007) largely agrees with the Elguindi and Giorgi (2007) work, and predicts a decrease of six meters in sea level from 1975 to the end of the 21st century. Based on the simulation, the drop in level is the result of increased surface evaporation exceeding the augmented run-off from the Volga caused by enhanced precipitation in the Volga catchment basin. Because the model did not include "direct anthropogenic influences upon river hydrology, such as water extraction and dam building" (Renssen *et al.* 2007), it is reasonable to expect an even greater drop in sea level.

A significant decrease in sea level, in combination with evaporation and increasing temperatures may particularly affect fisheries, infrastructures, human health, tourism, and biodiversity.

The reduction in ice cover, particularly in northern areas, may impact the population of seals. This species, endemic of the Caspian, uses floating ice as pupping sites and a drastic reduction of cover may negatively affect its reproductive success. Evaporation, increase in sea temperatures, and consequent changes in water salinity has the potential to

[17] Net sea-level-rise or drop due to various components, mainly river run-off, precipitations, and evaporation.

impact fish stocks and put additional stress over the already imperiled sturgeon population. Furthermore, a reduction in sea level would increase costs for industry (mainly oil and gas) and transports as it would require modification of structures and procedures in response to the new conditions.

Finally, this scenario represents a potential health hazard. The Caspian Sea has been characterized in the past by significant fluctuations in sea level, whose causes have not, as yet, been completely uncovered. They may include changes in precipitation and run-off, along with tectonic and carsic movements and other factors. Nevertheless, awareness of the unpredictability of sea level has not discouraged coastal developments from occupying new land once the sea has retreated. As a result, past rise in sea level has caused vast damages, for instance on the Russian coast (Frolov 2000; GEF 2002).

There exists the possibility that a new drop in sea level may again produce an unregulated rush to occupy newly available land. As a result, the populations would risk contact with a range of potentially very dangerous substances that are presently locked in the sediments of the basin (Figure 8).

The increase in temperatures could also promote the generation of algal blooms, which have recently been recorded along the coastal areas of Iran (Amy Evans, personal communication), in the south of the Caspian. The formation of red tides would be a health threat, and cause damage to tourism as well as a problem for fisheries and aquaculture.

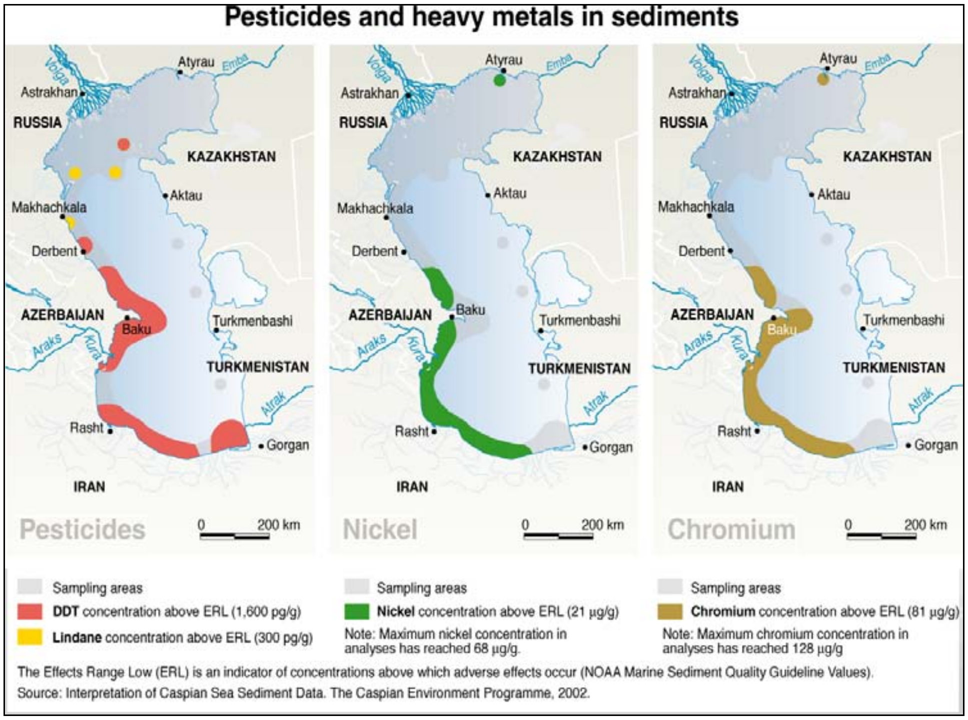
2.2.1 Stressors in the Caspian Sea

As introduced above, climate change events will potentially interact with current stresses, in particular pollution and unregulated coastal development.

Industrial emissions, toxic and radioactive wastes, agricultural run-off, sewage, and leaks from oil extraction and refining are the major sources of pollution in the sea. The sources are both local and off-site. Due to its vast drainage basin, the Volga is the principal contributor of Caspian nutrients and the projected increased run-off (see climate science section) may amplify the risk of eutrophication and algal blooms in the shallow northern part of the sea.

Other impacts include overfishing and habitat destruction in coastal areas, the latter due mainly to damming and construction of hydroelectric plants on the Volga. The combination of climate change and current stressors has the potential to impact fisheries, human health, and biodiversity.

a



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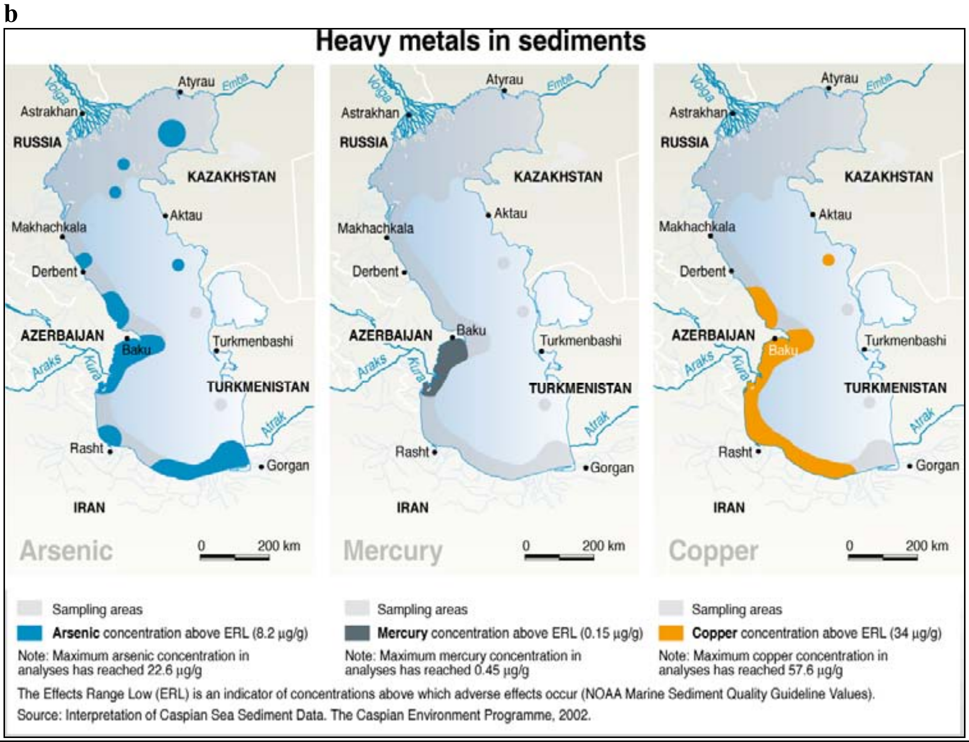


Figure 8 Pesticides and heavy metals in the sediments of the Caspian Sea. Source: Erin Grid, "Erin Grid Website," Erin Grid, URL.

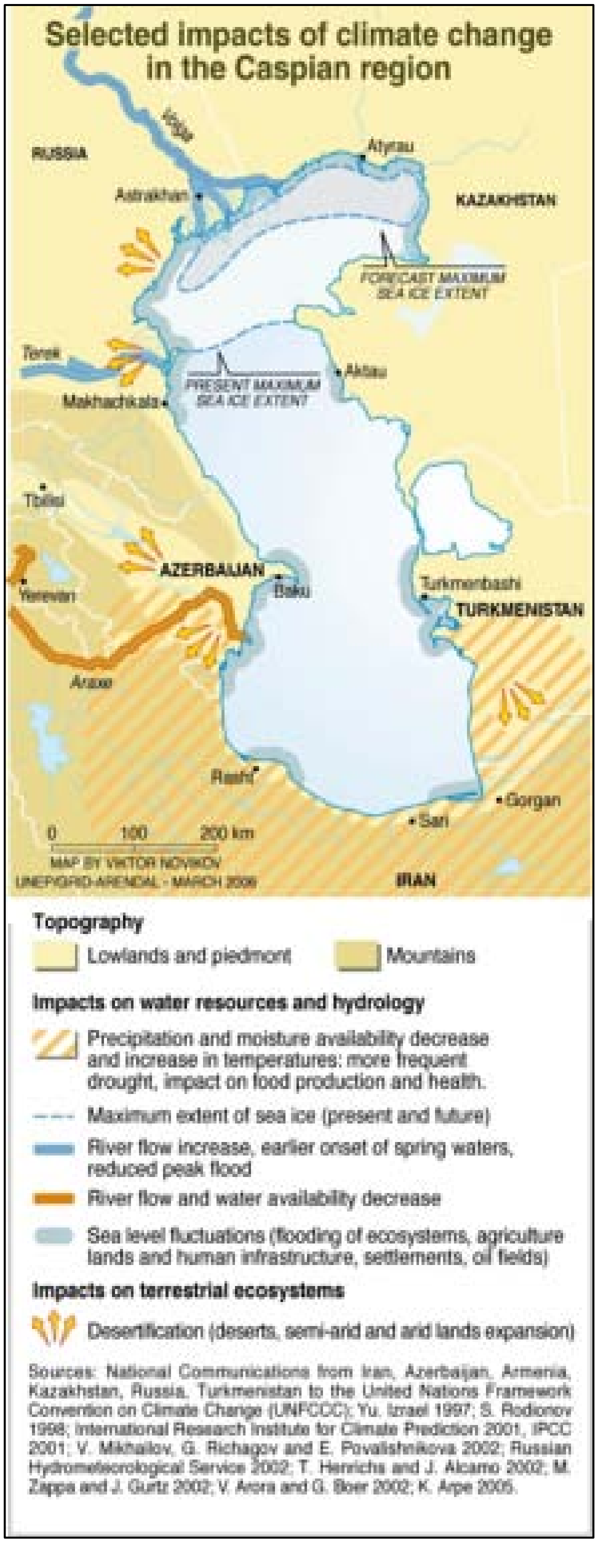


Figure 9 Possible impacts from climate change in the Caspian Sea basin.

Figure 9 shows some other climate change impacts described in the sources listed at the bottom of the figure itself. In case the projections described above would turn out to be inaccurate, or simply wrong, and the basin experiences a rise in sea level rather than a drop, the map shows areas at highest risk of inundation. The peninsula of Baku, site of important oil and gas industries, would be one of the most severely affected.

Increases in temperature around the basin are also likely to extend arid conditions, with impacts mainly for agriculture production.

2.3 Mediterranean Sea

Based on the projections presented in the climate science section, southeastern Europe, including the East Adriatic and the Mediterranean coast of Turkey, will experience an increase in annual mean temperatures, number of dry days, and length of heat waves, with a concurrent decrease in precipitation, frost days, and overall run-off. These events may trigger more forest fires in coastal areas, and affect river flow and groundwater supplies thereby impacting coastal agriculture, local biodiversity, and wetlands. Most of the following discussion focuses on impacts originating from sea-level-rise (SLR) and storms. To begin, it should be pointed out that because of tectonic activity, changes in density of deep waters, and local changes in air pressure systems, the Mediterranean is far from being the ideal place to gather meaningful forecast data on sea levels (Karaca and Nicholls 2008).

2.3.1 East Adriatic – Northern areas, Croatia, and Albania

High Adriatic

From data monitoring of Venice and its lagoon, a long-term trend of rising sea level has been clearly established for the north Adriatic coast. This phenomenon is due both to global changes in sea level and to land subsidence, particularly in deltaic areas. This is exacerbated by water surges due to storms and by particularly strong winds typical of the Adriatic basin such as the Bora (cold, dry, northeastern wind) and Sirocco (south-southeastern wind). The combination of these factors has increased the frequency and intensity of floods in the northern Adriatic coastal areas (Valiela 2006).

Croatia

Currently there is a lack of sea level projections for the Croatian coast. Only one study has been run to date with the collaboration of UNEP-MAP and the Climate Change Group of the University of East Anglia. The modeling exercise produced projections of sea-level-rise for the 2030, 2050, and 2100 time horizons and for two locations on the Croatian coast: the island of Cres (with the main city, Losinij), and the Kastela Bay (Baric *et al.* 2008). The results are shown in the table below.

Table 6 Croatian SLR projections.

2030	**2050**	**2100**
+18 ± 12 cm	+38 ± 14 cm	+65 ± 35 cm

Source: Baric *et al*. 2008.

To add to the uncertainty, the East Adriatic coast is tectonically active, and observations of sea-level-rise at different locations recorded between 1956 and 1991 show great differences, with average sea level rising in one site and dropping in another (Ref.).

A United Nations Development Programme (UNDP)/Global Environment Facility (GEF) project is under way to produce the first national report on climatic changes, vulnerability, and national adaptive capacity. Because of the lack of consistency in the data, the project is conducting a qualitative assessment, based on expert judgment, of the vulnerability of coasts to 20 and 86 centimeter sea-level-rise (Baric *et al.* 2008)[18].

The Croatian coastal zone has high socioeconomic and biodiversity importance. The narrow coastal strip (1-5 km) has a population density higher than in the hinterland (Baric *et al.* 2008). Coastal tourism is a major source of revenue, with 95% of all tourists remaining on the coasts. Maritime transport and shipbuilding are important industries. Fisheries and aquaculture have been on the rise, and agriculture is widely practiced on the

[18] The article does not clarify why the experts chose 20 and 86 cm SLRs.

coasts, particularly in the alluvial plain[19] of the Neretva River. Moreover, cities of historic value are scattered all along the coast.

The high economic, social, and cultural value of Croatia's coast indicates that its socioeconomic system has high sensitivity to climatic hazards. However, from the biophysical point of view, the sensitivity of the Croatian coast to sea-level-rise and storm surges is generally low (Baric *et al.* 2008, Republic of Croatia 2006). In fact most of the coastline (including the many islands) is rocky, with few steep gravel or sandy beaches, which are little prone to erosion. The only areas potentially exposed to threats are small, uninhabited islands, the coastal plain between the cities of Zadar and Sibenik, the alluvial plain of the Neretva, and a few other areas. The current UNDP/GEF study shows that a twenty centimeter sea-level-rise would not have a significant impact. Some cities like Rovinij (on the island of Cres), Pula and Split (on the mainland) are already experiencing some flooding events and their frequency may increase slightly (Baric *et al.* 2008). It is possible that the SLR will cause minor problems to some outlets of sewerage systems, and to salt pangs. Minor flooding may also occur in the plains of the Neretva, Rasa, and Cetina rivers.

Contrastingly, a sea-level-rise of 86 centimeters would constitute a much more serious threat considering that tourism, fisheries, and shipping infrastructures are often built right up to the shore. Marinas may be seriously damaged, even if one grants that many are built on floating docks which allow them to adapt more easily to changes in water level (personal experience). The entire low-lying Istrian west coast, and the aforementioned cities, with the addition of Dubrovnik, Omis, and Trogir, would be exposed to a much higher risk of flooding from sea rise and storm surges, and agriculture activity in the Neretva alluvial plain may be seriously impacted.[20] Vulnerable spots include two freshwater lakes (both named Vrana), one on the Cres Island and another close to city of Biograd. Saltwater intrusion may occur in the latter (used for irrigation in agriculture), as the lake is very close to the shore, and the short land strip that separates it from the sea is of high porosity, karstic in nature (Baric *et al.* 2008). However, in general it is not possible to assess the effects of sea-level-rise on saltwater intrusion along the Croatian coast because there is no available data on current groundwater table levels or soil permeability.

In summary, SLR effects in Croatia will be localized; it is more complicated to assess the risk to the 1,185 islands, some of which are of high historical, biodiversity, and tourism value.

Albania

The socioeconomic system of the Albanian coast is highly sensitive to flooding and increased storminess. This is mainly a result of unregulated urban development that has

[19] "An alluvial plain is a relatively flat landform created by the deposition of sediment over a long period of time by one or more rivers coming from highland regions, from which alluvial soil forms" (*Wikipedia*, "Alluvial plain," http://en.wikipedia.org/wiki/Alluvial_plain.).

[20] The alluvial plain of the Neretva has been reclaimed for agriculture using dikes and pumping stations.

allowed building right up to the shoreline, exposing infrastructures to a high risk of damages (World Bank Staff, personal communications).

Considering a 2100 time horizon, “a sea-level-rise of 48-60 cm would result in direct flooding of coastal areas” and significant saltwater infiltration (Republic of Albania 2002), whereas the projections for 2050 (20 to 24 cm) will not have major impacts. SLR particularly threatens beach areas in the northern and central zones of the Adriatic. People, infrastructure, tourism (hotels), roads, and agricultural lands are vulnerable. Again considering the 2100 time horizon, the Republic of Albania National Communication to the UNFCCC (2002) identifies particularly vulnerable areas affected by land subsidence (Shengjin, Kune-Vain, Tale, Patok, Ishem), roads like the new Fushe Kruje- Lezhe, and former swamps (Durres, Myzeque, Narta, and Vrug). It is also expected that wetlands will be threatened by the reduction of stream flow which is likely to result from the reduction in run-off projected for the region (see climate science section).

Mediterranean coast of Turkey

The Mediterranean coast is diverse both from geomorphological and socioeconomic points of view.

Karaca and Nicholls (2008) affirm that “there are no reliable long-term sea-level measurements in the eastern and southern Mediterranean.” However, based on global projection from several studies, and anecdotal evidence, it is expected that sea-level-rise and storm surges will especially impact tourism and agriculture along the Mediterranean coasts of Turkey. The impacts are likely to be localized, as in general the geophysical characteristics of Turkey’s coastline indicate a low vulnerability to SLR (Republic of Turkey 2007).

Turkey has tectonically active, high-elevation terrain (85% of Turkey is above 450 meters). Black Sea coasts included, 69% of Turkish coasts are rocky, 19% sandy, and the remaining 12% are swampy deltaic plains often comprising wetlands and lagoons. According to the vulnerability study by Karaca and Nicholls (2008), these low-laying areas are the most vulnerable to flooding, erosion, and saltwater intrusion assuming a one meter SLR and storm surges. Several deltaic plains (e.g. Gediz, Seyahn and Ceyhan) are particularly vulnerable because of land reclamation for agricultural purposes (Karaca and Nicholls 2008).

While the Black Sea coast of Turkey provides most of the tonnage of the fishery industry, the Mediterranean coasts and the coasts of the Marmara Sea are most important for the tourism industry. This sector has a high growth rate and increasing sensitivity to SLR as most of the newly developed accommodations are built right up to the shoreline. Moreover, tourism drives most of the large increase in urbanization toward the coast and large coastal cities like Izmir, Adana, Antalya, and Alanya on the Mediterranean, and Istanbul on the Marmara. The increase in population in coastal cities significantly amplifies the sensitivity of the socioeconomic system to sea-level-rise. Istanbul is a particularly sensitive site, as ten percent of the population lives within one kilometer of the shore, and the city by itself accounts for 21% of the national GDP. The major threats are actually from saltwater intrusion, particularly to two coastal lagoons and to Terkos lake, the freshwater supply of the city (Karaca and Nicholls 2008).

The overall vulnerability of the Turkish coastline to SLR is estimated to be low to medium. However, increases in economic development are expected to increase the overall sensitivity. Several important sites are going to be significantly affected, particularly Saros bay, and the eastern Mediterranean (Hatay Yumurtalik, Iskenderun). Storms are also already heavily affecting the Izmit-Glolcuk bay in the Marmara Sea, Izmir Bay in the Aegean Sea, and the Fethiye and Antalya gulfs in the Mediterranean. Damages are projected to increase in absence of an adaptive response. Furthermore, sensitive cultural and historical sites in Istanbul, and on the Aegean and Mediterranean coasts, like the ancient Greek cities of Phaselis and Patare, are already threatened by wave action.

2.4 Black Sea

At present there is a serious lack of studies addressing possible climate change trends in the Black sea region, and a lack of consistency in the few existing reports.

Regardless, a recent article has focused the attention on some climatic changes along the southwestern coast (Bulgaria and European side of Turkey) of the Black Sea (Alexandrov *et al.* 2005). This modeling study, based on the A2 and B2 IPCC scenarios, projects that in the 21st century the western coast of the Black sea will experience an increase in the trends observed during the last two decades of the 20th century, particularly in freshwater shortages originating from increasing temperatures and droughts, decreasing precipitations, decreasing run-off, and diminishing groundwater levels. Although the A2 and B2 scenarios do not show complete agreement in the rate of change, they do agree on predicting increasing warming until 2080, with temperatures that increase by 7to 8 ºC by the end of the century under the A2 scenario. The model also pointed to a trend that can lead to a decline in precipitations of up to 70%. As this area of the Black Sea is important for the agricultural sector, an increase in demand for irrigation has to be expected. This is expected to clash with the overall reduced water availability.

Valiela (2006) reports that the rate of sea-level-rise has been higher in the Black Sea than in the Mediterranean (27 ± 2.5 mm per year, versus 7 ± 1.5 mm per year), and this has repercussions both on urban centers, infrastructures and wetlands. For instance, the Bulgarian coast is mostly flat and therefore physically sensitive to SLR; the overall vulnerability is high because of the unregulated development. Increased erosion and flooding would negatively affect tourism assets, infrastructures, and the energy sector through impacts on coastal oil and gas refineries (Milen Dyoulgerov World Bank Staff, personal communication).

Because coastal areas in Bulgaria, Ukraine (chiefly Crimea), and some parts of Georgia are already affected by chemical and/or wastewater contamination, inundations would likely exacerbate coastal pollution. Furthermore, SLR and storm surges could have an impact on the erosion affecting the Black Sea coast between Turkey and Georgia, exacerbated because of unlawful urbanization, sand mining, and poor judgment in site selection, design, and construction of coastal structures, especially harbors (Yuksek *et al.* 1995).

Karaca and Nicholls (2008) report tide gauge data collected from 1930 to 2000 for the following cities: Varna (Bulgaria), Constantza (Romania), Sevastopol (Ukraine), Tuapse (Russia), Pito (Georgia), and Batumi (Georgia). The relative sea-level-rise over 70 years is 3.7 millimeters per year for Pito, 6.8 millimeters per year for Batumi, and 1 to 2 millimeters per year for the other cities, which is consistent with global trends. The results seem to indicate that the Georgian coast is subsiding with respect to the rest of the Black Sea basin. The Russian coast will be particularly vulnerable to erosion due to high economic activity and development of coastal tourism; it is also expected that several large cities along riverbanks will be impacted (Frolov 2000). It is expected that at this rate cultural and industrial areas will be flooded and salt water will infiltrate coastal aquifers. For its part, Ukraine is already experiencing erosion problems that caused the loss of housing, arable land, industrial sites, and traditional spas and resorts for mud treatment important to the tourism industry.

Sea-level-rise for the Black Sea coast of Turkey has been estimated at 1 to 3 millimeters per year (Karaca and Nicholls 2008). Flat areas vulnerable to sea-level-rise and storms are rare, and are represented mainly by deltas and lagoons (19% of Turkish lagoons are on the Black Sea). The major deltaic areas are the Yesilirmak, Kizilirmak, and Sakarya. The first two would be particularly sensitive because of agricultural development. Despite a generally low vulnerability of the biophysical system, a sea-level change of this magnitude would significantly impact the coastal socioeconomic system. Similarly to the Mediterranean coast, the Black Sea coasts have high population density concentrated in coastal cities. Population livelihood is based on fisheries and agriculture, and both activities are going to be affected by sea-level-rise. In the year 2000, 76% of the Turkish fishing tonnage came from the Black Sea. The industry is already threatened by overfishing and pollution, so climate change could worsen the situation (see 2.4.1). Storm surges already affect some settlements (Karaca and Nicholls 2008) and worsening conditions may bring damages to the 23 ports along the Black Sea. Furthermore, storms, erosion, and sustained flooding are predicted to damage the very important shoreline east-west road system that runs along the coast.

The Black Sea is a very important source, refinement point, and transport route for oil and gas. There is a concern that oil and gas refineries and infrastructure (e.g. in ports like Batumi) will be impacted by SLR, increased storminess, and erosion on the Russian, Bulgarian, Ukrainian, and Georgian coasts.

2.4.1 Stressors in the Black Sea

The coasts of the Black Sea share most of the problems affecting the Baltic. Three main stresses have caused major degradation of its natural resources:

1. Water pollution: eutrophication/nutrient enrichment (sewage and inorganic nutrients), and chemical pollution (including oil and other industrial pollution)
2. Biodiversity changes: introduction of alien species
3. Unsustainable use of natural resources: overfishing.

Many rivers open up into the Black Se, and transport sediments, nutrients, and chemicals collected over vast drainage basins. Three of the four biggest rivers in Europe end in the Black Sea, and the Danube (the second biggest) has a basin that covers most of central Europe. Exactly like in the Baltic the ensuing eutrophication problem is exacerbated by the enclosed nature of the basin, and by its slow water exchange with the Mediterranean. Despite the 20% reduction in nitrogen emissions from the Danube in the last ten years (GEF 2007), agricultural and livestock wastes are still an issue, and eutrophication may be worsened by rising temperatures in the Black Sea (Figure 10).

Rising temperatures and eutrophication may lead to an expansion of anoxic areas with consequent impacts on fisheries and tourism. The fishery sector has already suffered greatly in terms of reduced catches, mainly due to overexploitation and introduction of exotic species. In the mid 1980s, the wart comb jelly *Mnemiopsys leidyi* (Phylum Ctenophora) was accidentally introduced in the Black Sea (most likely through the ballast water[21] of ships), and caused a collapse in catches by predating on fish larvae and on their preys. The spread of other exotic species may be favored even more by the warming of the sea.

Sea-level-rise and increased storminess represent an additional threat with respect to chemical pollution. Coastal landfills have been identified as pollution hot-spots in the Black Sea (GEF 2007); in areas like the coasts of Georgia sea-level-rise and coastal erosion may further damage these landfills and incease the amount of pollutants flushed to sea (Darejan Kapenadze World Bank Staff, personal communication).

Finally, the damming and channeling of rivers, along with ill-managed coastal development are responsible for alteration of the sediment balance, distribution, and a resultant erosion problem. In Russia, Bulgaria, Ukraine, and Georgia there is a major issue with unregulated construction close to the shore. This promotes erosion and increases the sensitivity to climate impacts.

[21] Ballast water is the water pumped inside a ship to provide stability; it is pumped in and out of the ship at need.

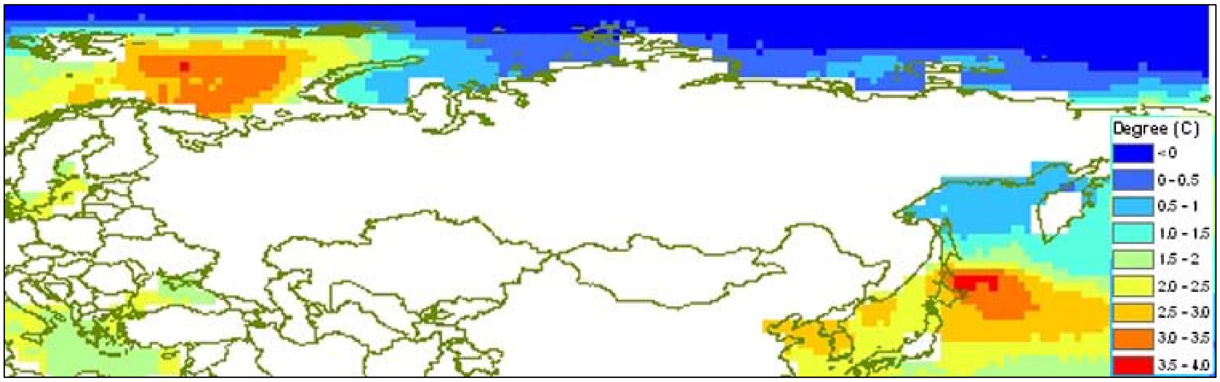


Figure 10 Sea temperatures are rising across the Baltic, Black, Mediterranean, and Arctic Seas. Data is not usually available for the Caspian.

2.5 Arctic – Russian coasts in the arctic

The arctic is one of the areas most vulnerable to climate change. Arctic vulnerability may increase due to its rising socioeconomic importance. The IPCC (2007) reports that from 1980 to today the arctic has had the highest warming rate, with an increase of approximately 1 ºC per decade in the winter and spring months. Future changes will have a major impact on the arctic ecosystem and biodiversity and will modify the availability of natural resources. These aspects are analyzed in the biodiversity section of this Umbrella Report therefore they will not be treated further in this section.

Declining snow cover and increasing precipitations are expanding the river flow and the amount of run-off into most of the Arctic Ocean (Anisimov *et al.* 2007). This, in combination with the melting of glaciers and the retreat of summer sea ice cover is driving a global rise in sea level that along the arctic coasts has been measured at between ten to twenty centimeters in the past century, and is projected to grow of additional ten to ninety centimeters over the course of this century (ACIA 2005).

On the arctic coasts of Russia, sea-level-rise is already accelerating erosion rates. The process will be exacerbated by the thawing of the permafrost, which makes the soil less resistant to wave impact, and by the reduction in sea ice, which allows higher, stronger waves and storm surges to hit the coast. Erosion, flooding, and receding coastlines will impact both natural and socioeconomic systems. Flooding and storm surges are already threatening wetlands, settlements, and industrial facilities, some of which will be forced to relocate. Thawing of land ice and permafrost will threaten the stability of buildings and industrial installations like oil and gas pipelines, while at the same time damaging roads and shortening the periods when ice roads can be used for travel, thereby disrupting transport and making communications more difficult and costly (ACIA 2005).

On the positive side, the reduction in sea ice will likely open new shipping routes in the arctic, and increase marine transport and access to resources like gas and oil. The opening of a northern passage is likely to shift trade routes, change trade links and transportation networks, and generally trigger major development. This will undoubtedly raise sovereignty and environmental concerns that will need to be addressed (ACIA 2005).

2.5.1 Destabilization of the arctic coasts, erosion, and economic damages

The arctic is exposed to a range of environmental impacts of human origin, including pollution, overharvesting of natural resources, and habitat conversion (see biodiversity section). Warming of the climate is expected to boost the drilling operation for oil and gas and consequently more infrastructures and facilities will be built.

This type of development will need to be regulated and will need to take into consideration synergies between operations on the coasts and sea-level-rise. Past failures to do so are already inflicting damages and raising costs for industry. The oil storage facility at Varandei on the Pechora Sea, on the southeastern part of the Barents Sea, exemplifies the consequences of synergy between impacts on the local environment and climate change. The area is geologically fairly stable, however industrial constructions have damaged the natural environment and reduced the stability of the coast so that the erosion rate is twice as fast than in areas free of human activity (Ogorodov 2004). Coastal retreat combined with the ensuing direct effects of increasingly strong storm surges and sea-level-rise have already damaged facilities and housing and are threatening the airport area. The problem will be exacerbated further as the climate continues to warm while sea ice cover decreases, giving way to stronger waves and greater sea-level-rise (ACIA 2005).

3. Adaptation strategies

Climatic changes both aggravate old issues and bring new threats to coastal zones. Models predict that damages will increase if adaptation measures are not implemented.

Today, as in the past, experts and stakeholders most frequently resort to protective measures against storms and sea-level-rise. The coast of Poland is protected by more than 200 kilometers of hard structures that began to be put in place in the 19^{th} century. Similar hard structures, as well as dunes, have been adopted along the coasts of Turkey, mostly on the Black Sea side.

Given the scale of the climatic phenomena and the extent of the territory likely to be affected, hard structures are not an economically viable solution. Besides, barriers are known to modify local currents and sedimentation patterns with the result being a mere shift of erosion problems elsewhere along the coast. In some cases protective structures will still be necessary, for instance to defend important historical port cities in Croatia (Dubrovnik, Split), or possibly for cultural sites like the ancient Greek cities of Phaselis and Patara in Turkey. However, the consensus is that the climate change challenge should be used as an opportunity to adopt a long-term strategic approach to coastal management; this is reflected in some of the adaptation options described in Table 7.

Coastal areas have always been known as dynamic systems, shifting between different states. However changes are now occurring more rapidly and are affected by events characterized by a high level of uncertainty. As a result, we must prepare both for projected changes for the unexpected. Adoption of an *adaptive management* approach is crucial to deal with the uncertainty of complex climate change events. Here, *adaptive* does not refer to reaction or preparation to climate change, but to a management framework based on implementation, monitoring, and periodic reassessment of adaptation measures; it requires that the measures against climate change have clearly defined, measurable goals and carefully planned monitoring systems, so that the observed failure or success will allow us to learn more about our changing environment and hone the adaptation solutions (Box 2).

No matter which adaptation option is chosen, this management approach should underpin the selection process in order for adaptation to be ultimately successful.

Box 2 Adaptive management

"Adaptive management is an approach used to guide intervention in the face of uncertainty about the system. The main idea is that management actions are taken not only to manage, but also explicitly to learn about the processes governing the system. This new information is then used to improve understanding of the system and hence to inform future management decisions. Monitoring is a key component. A plan for learning is fundamental – just to say 'oh that didn't work, let's try something else' is not adaptive management" (Shea 1998).

Table 7 Adaptation measures organized by impact.

Biophysical events	Anticipatory – Planned Adaptations	Actors in charge of the measures
Erosion (SLR)	• Protect – accommodate – retreat • Beach nourishment • Wetland protection and restoration • Revised spatial planning and water resources management	• Ministry of Environment or Infrastructures provides guidelines and legal framework. • Some implementation can be done through local authorities in collaboration with the private sector and the public-at-large.
	• Detailed vulnerability assessment	• Vulnerability assessment usually contracted to scientific institutions (e.g. universities) often reporting to the Ministry of Environment.
Inundation (SLR + Storm surges)	• All the above	• See above.
	• Weather/inundation forecast and warning system	• HydroMet institutions are in charge of weather forecast (often publicly financed and answering to the Ministry of Environment).
	• Preparation and implementation of an emergency/disaster preparedness plan	• Ministry of Interior is in charge of preparedness plans and coordinates with regional and local authorities, civil protection, and fire departments.
	• Awareness raising campaign – hazard awareness education.	• Awareness campaign usually managed by Ministry of Interior or Education.
	• Disaster risk insurance and weather risk hedging instruments	• Disaster risk insurance usually managed by private sector, professional market players, and sometimes Ministry of Finance.
	• Retrofitting of buildings	• Construction or retrofitting codes come from central government.
	• Regional disaster task teams deployable across borders	• Central governments acting under transboundary international agreements and international organizations
Floods, from upstream	• Increase public awareness of flooding – hazard awareness education.	• Ministry of education, in collaboration with regional and local authorities, is in charge of awareness campaigns.
	• Flood forecast system • Warning system	• Flood forecast and warning system is a duty of the HydroMet institutions and civil protection units.
	• Revised spatial planning, retrofitting of buildings, and water resources management	• Central or regional government directly, or indirectly through local government mandates
	• Watershed modeling exercise with hydrological models that keep climate change into consideration	• Scientific institutions often reporting to Ministry of Environment

Biophysical events	Anticipatory – Planned Adaptations	Actors in charge of the measures
Floods, from upstream (continued)	• Disaster risk insurance and weather risk hedging instruments • Regional disaster task teams deployable across borders	• Private sector, professional market players, and sometimes Ministry of Finance • Transboundary international agreements could be present allowing rapid intervention of relief efforts across borders.
Changes in run-off	• Adaptation to droughts and subsequent reduction in water quantity and quality – maintenance of the water infrastructure and delivery system to reduce water losses and upkeep of reservoirs	• Ministry of Agriculture in collaboration with users' associations in charge of monitoring at the local level.
Saltwater intrusion	• Revised spatial planning and water resources management • Saltwater intrusion barriers • Injection of freshwater into aquifers	• Central government provides the legal basis, and scientific institutions set standards and bring technical expertise.
Sea temperature and acidification	• Monitoring system for physicochemical parameters • Monitoring of seasonal and geographical location of nutrients run-off • Promote best environmental practice for site-selection processes in aquaculture activities • Concerted effort for monitoring and assessing migrations and health of fish stocks • Concerted effort for reducing fishing pressure • Monitoring and control of introduction of exotic species, and eradication or containment methods (measures include, but are not limited to, best practice requirements for the shipping and aquaculture industry) • Transboundary effort at the basin scale for reduction of nutrients inputs	• Monitoring is managed by the environmental network made up by the Ministry of Environment and local monitoring agencies. • Ministry of Agriculture, Fisheries, and/or Environment • Ministry of the Environment is most likely to set the strategy for monitoring and controlling exotic species. The port authority may have the mandate to execute, monitor, and enforce the provisions. • Collaboration of central governments through international agreements

Sources: Zakout *et al.* 2008; Cestti *et al.* 2003; Klein *et al.* 2001.

3.1 The basics of adaptation: Protect – Accommodate – Retreat

Climate change affects coastal areas through a combination of hazards. As such, adaptation to inundations originating from sea-level-rise and storm surges is based on three general strategies (Klein *et al.* 2001, Nicholls and Klein 2005):

1. Protect – reduce the likelihood of the hazard
2. Accommodate – reduce the impact of the hazard event
3. Retreat – reduce exposure by moving away from the source of the hazard.

Table 8 Three strategies (a combination of policy and technological options) for adaptation to SLR and storm surges

Protect	Accommodate	Retreat
• Dikes, levees, floodwalls • Seawalls, bulkheads • Groynes • Floodgates and tidal barriers • Detached breakwaters • Periodic beach nourishment • Wetland restoration • Afforestation • Wooden walls • Stone walls	• Emergency planning • Insurance • Modification of buildings to cope with floods (strengthen and lift) • Improved drainage • Strict regulation in hazard zones • Modification of land use planning	• Increase or establish retreat zones • Relocate threatened buildings • Phase out or ban development in areas susceptible to flooding • Rolling easements, erosion control easements • Upland buffers

Similar policy and technological options are also adopted to cope with river floods caused by extreme rainfall events in the catchment upstream of a coastal area (Table 7). Possible adaptation measures include: increasing public awareness of possible floods, maintaining flood forecasting and warning systems, and reinstating floodplains through appropriate spatial planning.

Protection measures are also being studied to cope with the issue of seawater infiltration in coastal aquifers. This phenomenon is the first impact of sea-level-rise and affects the socioeconomic system by contaminating water resources necessary for agricultural practices and household use.

3.1.1 Accommodate, Retreat, and Revised Spatial Planning

The adaptation measures in Table 7 reduce coastal vulnerability by reducing the sensitivity of the system (either natural or socioeconomic) to climatic events (see Figure 4). Some of the options improve the resilience of the system by counteracting the effect of other external stressors that tend to increase the sensitivity to climate change[20] (Figure 5). Albania and Georgia, for instance, should enforce *Accommodate* and *Retreat* measures based on rolling easements and *Revised Territorial Planning* (Box 3) to tackle the unregulated (and at times illegal) coastal development

[20] E.g. overexploitation of resources, pollution, decreasing freshwater availability, sediment starvation, unregulated urbanization

of housing and tourism infrastructure which increases the risk of damages to material assets (i.e. it increases the sensitivity of the socioeconomic system to sea-level-rise and storm surges).

Box 3 Easements, setbacks, and zoning

Erosion easements

Erosion easements, defined as "legal agreements between a landowner and a land trust or the government agency that restricts development in erosion-prone areas," can be designed to:

- prohibit any type of development or control the size and/or density of structures,
- prevent shoreline hardening activities and/or specify what type of shoreline stabilization can be used,
- and prohibit the cutting of natural vegetation along the shoreline or restrict erosive activities.

In order to effectively protect property and coasts, easements can be coordinated at the regional scale so that all the properties over a large segment of coast have the same rules applied to them.

Rolling easements

These agreements are placed on a shoreline property to prevent the owner from holding back the sea. All other activities are allowed; there are no restrictions on building on the property. If the sea advances, the easement "rolls back" landwards. This is designed mainly to protect wetlands. Being aware that the property is susceptible to erosion, the owners have an incentive to build smaller mobile structures, easy to relocate. This, along with a prohibition on containing the sea, allows wetlands and coastal habitats to migrate naturally inland.

In the US, easements are voluntary, and land owners that choose to place an easement on their property receive a property tax break. This makes them more appealing than other regulatory approaches. On the other hand, they are difficult to enforce and not as effective as setback lines and zoning overlays.

State mandated setback regulations

Construction setback regulations mandate that development must be a certain distance from the water. These, however, require good scientific data; they should be based on erosion data that is often difficult to get. Setback lines in South Carolina are re-assessed every eight to ten years. At times, establishing new lines means that the state will need to compensate owners for their unbuildable property.

Zoning and erosion overlays

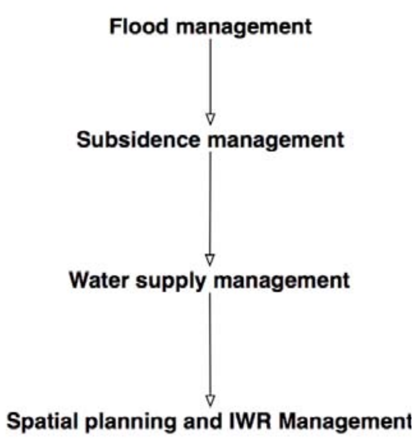
These strategies rely on state planning to limit development in erosion or flood prone areas, to minimize damages to property, and to eliminate the construction of defense structures. They can also contain rules for set-back lines and prevent clearing of native vegetation. However the government must have the capacity to regulate these measures; they require accurate data on areas at risk of erosion and flood, and may result in expropriation if development is already present.

Source: NOAA Office of Ocean and Coastal Resource Management, “Shoreline Management: Utilize Erosion Control Easements,” US Department of Commerce, National Oceanic and Atmospheric Administration, http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_easements.html.

A reassessment of flood management will also be necessary in areas at risk of subsidence, particularly deltas and alluvial plains (e.g. Neretva in Croatia and Danube in Romania). These areas are especially vulnerable to SLR and storm surges because they are usually densely populated, characterized by fast economic development, and at the same time they are the meeting point of saltwater and riverine freshwater (hence more exposed to floods).

In these areas flood management should be linked with spatial planning and integrated water resources management (Box 4). Adaptation to inundation from extreme rainfall events, sea-level-rise, or a combination of the two needs to take into consideration the component of local subsidence. In deltaic areas this phenomenon can far outweigh climate change as the main cause of inundation, and it is often aggravated by the abstraction of groundwater for production activities and household use. The problem can be tackled by creating incentives for people and businesses to move to other areas of the coast, where their operations and water needs are deemed less likely to affect subsidence. Ideally, spatial planning and integrated water resources management should guide such changes, and should be applied at the watershed scale to effectively protect material assets while at the same time regulating the quality and quantity of water reaching the coastal zones.

Box 4 Spatial planning in Jakarta



Jakarta, capital of Indonesia, experienced several floods of the downtown area in 2007, with two major inundations in January and November. Analysis of hydrological, geological, and sea-level-rise data shows that subsidence is the principal cause. The city is sinking mainly due to water abstraction from underground. The sinking rate is much higher than any increase in sea-level-rise (from 2007 to 2025 predicted increase in sea-level-rise is 4 to 6 cmand predicted subsidence is 40 to 60 cm). Subsidence is also enhancing the sensitivity to storm surges and periods of high tides. While immediate measures like dredging of canals and barriers are necessary, the long time solution consists in scaling up the intervention, moving from flood management to water resources management to urban and territory planning. In order to control the subsidence process, water abstraction must be regulated. One solution proposed to the city by external advisors and experts from the Dutch Institute for Delta Applied Research is to reduce water abstraction in the most sensitive areas of the city by modifying spatial planning and pushing businesses and residents out of these areas, thereby shifting the demand for water away from the areas at greatest risk of flooding.

Source: Deltares presentation, Meeting on the Experiences of Jakarta and New Orleans, World Bank.

Spatial planning at the watershed scale has been adopted in the Netherlands as a critical strategy to cope with the threats of climate change and increased river flow (Box 5). The strategy, known as "living with floods" or "room for the river", hinges on general revision of zoning and on setting aside areas to be flooded, in case of inundations due to extreme precipitation and river overtopping. The advantage of such a policy is that floods are controlled by being directed to areas designed to withstand such events. This is accomplished either by leaving these lands to nature, or by strictly limiting the type of allowed activities and enforcing precise building codes. While this strategy is, in the long-term, the most sound from a socioeconomic and environmental point of view, it must be recognized that it requires vast investments in the short-term and the advantages can be seen only over long periods. It follows that this strategy has economic sense mainly for areas where exposure and sensitivity are very high, and where the population affected and the value of natural and material assets are very large.

Box 5 Living with floods in the Netherlands

The government of the Netherlands, which has expertise in flood management, has integrated protective measures (dykes and barriers) with the use of "resilience strategies." These are based on the definition of risk associated with flooding (either from rivers, sea, or a combination of the two) as determined by the likelihood of a flood multiplied by the damage caused by it. Building higher dykes (strategy of resistance) is a very costly strategy when factoring the costs associated with a possible failure in protection (Vis *et al.* 2003). The sense of security provided by higher and stronger dykes promotes more investments in the vicinity of the defense structures. This, in combination with the rise in sea level outside the dykes makes a possible breach and flooding event all the more catastrophic. The strategy of resilience is based on reducing the risk of damages (living with floods) by trying to minimize the likelihood of a flood event and by allowing only certain areas to be flooded. The advantage is that the inundation is controlled, by being directed in zones that have been prepared for these occurrences through spatial planning and building codes.

3.2 Adaptation for the fishery sector

In the ECA basins, in particular in the Baltic, Black, and Caspian Seas, rising sea temperatures in combination with modifications in run-off due to changes in precipitation may impact the productivity of fisheries (see Table 4). The best adaptation option is to tackle those stresses other than climate change that increase the sensitivity of fisheries to climate change by negatively affecting fish stocks; overfishing, spread of exotic species, organic and inorganic pollutants leading to eutrophication are the factors that in the last decades have contributed to a drastic reduction in productivity of the fishery sector in these three basins. Given the nature of ECA sea basins, these results can be obtained only through a concerted international effort including the countries that are part of the drainage basins. In this respect the GEF transboundary project for the Danube has already obtained results in reducing the input of nutrients in the Black Sea, and the GEF Baltic Sea regional project is proceeding toward the realization of an integrated management of the basin.

3.3 Issues with the development of adaptation options

A strategic coastal management for climate change should be based on the following:

1. Development in coastal zones and in flood-risk zones needs to take into account climate change impacts, and as a result requires long-term planning in:
    a. Development objectives
    b. Transports and utilities
    c. Energy sector
    d. General land use regulations and spatial planning
2. Regional and national scale policies must be transferred down to the local level, empowering local authorities and giving them mandate for the implementation of long-term practical adaptation measures.
3. The strategies need to take into consideration the full set of options: Protect/Accommodate/Retreat.

Inclusion of options other than *Protect* will require difficult decisions and create some tension between stakeholders. In this respect it is necessary to recognize the local stakeholders as:

1. Directly affected categories: land and home owners, fishermen, etc.
2. Local and central government decision makers for coastal management (usually they also deal with development control and land use planning)
3. Public and private organizations (e.g. nature conservation and others).

The first group is likely to resist major planning changes that may affect their possessions. In this case information and education on the short-term and long-term impacts is critical, but it can be implemented only if there is a concerted effort from national and local authorities.

The implementation of successful measures will require "public inclusion, negotiation, integrate planning and implementation", along with necessary legislative changes that will need to underpin modification in spatial planning and land use, and allow for "compensation and acquisition of property in erosion and flood risk zones" (Few *et al.* 2004). Such a process is difficult and lengthy, which increases general vulnerability and makes the climate change threat even more challenging.

4. Adaptive capacity

4.1 Adaptive capacity in the context of coastal areas

Klein *et al*. (2001) define adaptation to climate change in coastal areas as a policy process organized in a series of steps involving consultation, decisions, and technical applications[21] (Figure 11):

1. Information – awareness (includes data gathering for vulnerability assessment)
2. Planning design
3. Implementation
4. Monitoring and evaluation.

This framework reminds policy makers and scientists that adaptation is part of a broader policy process, and identifies obstacles and opportunities (i.e. costs and benefits) for adaptation.

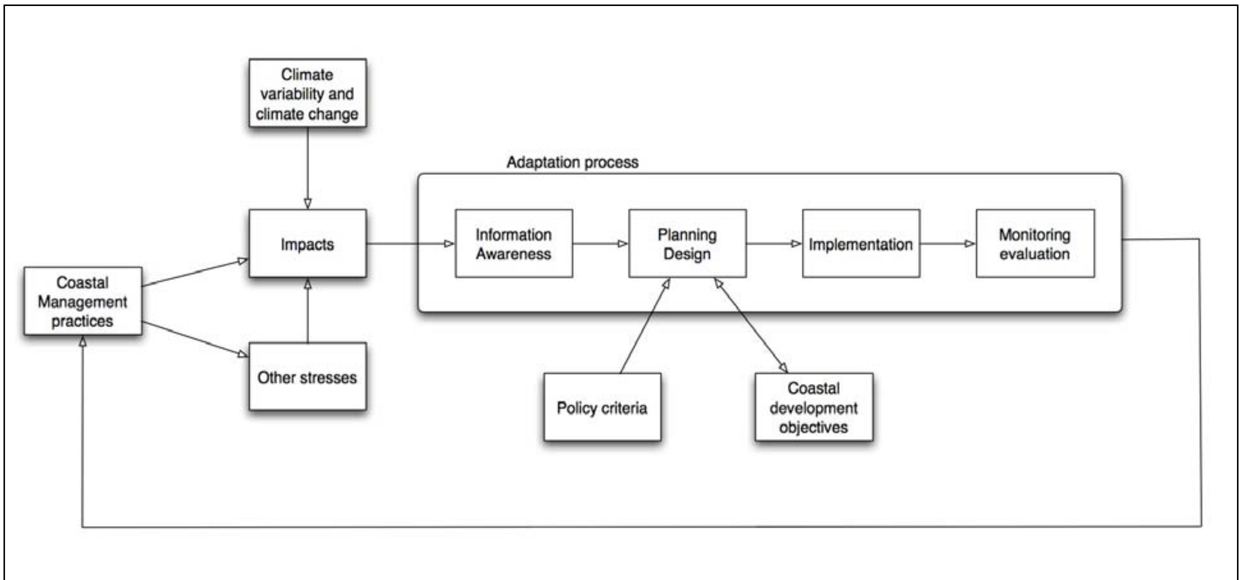


Figure 11 Framework for planned adaptation. Source: Klein *et al.* 2001.

The adaptation process starts with raising awareness of policy makers and the general public about the possible impacts of climate change, and gathering knowledge on the vulnerability of the coastal areas. The planning and choice of adaptation measures is influenced both by policy criteria (cost effectiveness, environmental sustainability, cultural compatibility, and social acceptability) and by coastal development objectives (Klein *et al.* 2001). Once the selected measures are implemented their monitoring and evaluation refines coastal management.

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[21] This model draws on the long-standing experience of countries like the Netherlands and Japan in dealing with climatic variability.

Adaptive capacity in the context of coastal areas can be defined as the capacity of the different actors identified in Table 7 (central government, local authorities, private enterprises, and the public-at-large) to drive and carry on the different phases of the adaptation process at a pace that is adequate to the rate of climatic changes. It is this capacity, rather than the mere availability of adaptation measures, that determines the vulnerability to climate change (in combination with exposure and sensitivity).

4.1.1 Awareness and education on coastal climate change is not adequate

Awareness and knowledge about the climate threat and about possible solutions is the first step in the adaptation process, and the basic condition for the development of an adequate adaptive capacity. In order to plan, implement, and respond promptly to adaptation measures, awareness must be equally rooted in experts of the socioeconomic and scientific disciplines, in government agencies, and in the public-at-large. The main aspects of awareness are:

1. Awareness of the different components of climatic exposure in coastal areas
2. Awareness of how the exposures affect coastal areas, the modifications induced and how these areas respond (naturally, e.g. coastal dynamics)
3. Knowledge of how climatic stresses and non-climatic stresses interact and compound their effects.

According to Tol *et al.* (2008), in the Black Sea and Mediterranean basin, awareness is limited to a few academics, and no knowledge has efficiently permeated the institutional levels in charge of spatial planning and coastal management. Bulgaria, Romania, Ukraine, Turkey, and Croatia (but also Italy, Spain, and others) have low awareness of the implications of climatic change on coastal areas, and currently have no plan for adaptation (Box 6). In the Baltic Sea, Estonia and Lithuania have low climate change awareness, and there vulnerability refers mainly to coastal ecosystems, while their socioeconomic systems have low overall sensitivity. Poland, on the other hand, has started a national coastal plan that includes analysis of SLR (Tol *et al.* 2008).

In general, the level of education and interest in the effects of climate change is low. The reasons for this are varied, but they are generally the result of current social, economic, and political challenges faced by the countries in the aforementioned basins, and their current focus on short-term issues.

Box 6 Adaptive capacity in Turkey

The main impediment to the development of adaptive capacity in Turkey is the very low awareness of coastal dynamics and climatic impacts, both in the institutions and among the public. Despite the plan by the Ministry of Environment to create a Department for Environmental Impact Assessment, no governmental body is presently dealing with the future consequences of sea-level-rise and other climatic events on coastal areas (Karaca and Nicholls 2008). Both a cause and a result of this condition is the lack of specific data and of appropriate methodologies to analyze impacts. However, part of the problem is also in the coastal protection law, which defines sea level as unchanging. A long-term coastal management plan is missing, and coastal issues are not a national priority unless they entail investments and infrastructures for the tourism industry. A result of this situation is the lack of consideration for increasing sea-level-rise and other environmental changes during the recent expansion of coastal infrastructure, both ports and protection works (Karaca and Nicholls 2008).

4.2 The way forward – Finding and analyzing the factors affecting adaptive capacity in ECA

Awareness and education are the *conditio sine qua non* for effective adaptation. The question remains, however, of what is the status of the other elements/dimensions of adaptive capacity if we assume that adequate awareness is attained.

Identifying the dimensions of adaptive capacity is a complex task. It is particularly so for coastal areas because of their geographical and multi-sectored nature. A first analysis of adaptive capacity can be obtained by using country-level indicators of resource endowments, but these seldom capture all dimensions, including effective strengths and weaknesses. For instance, the weight of institutions and social networks in determining the level of adaptive capacity may be very different from place to place (Brooks *et al.* 2005). To further complicate the picture, coastal areas are often simultaneously under control of regional, national and international authorities.

4.2.1 General questions –Indicators for adaptive capacity

Presently, some questions can be posed to identify the elements of adaptive capacity. Given that these elements must refer to the actors mentioned previously (central government, local authorities, private sector, public-at-large), some questions will address general dimensions (education, governance), while others will be specific for coastal areas and their impacts. The questions, taken from Tol *et al.* (2008), Yohe and Tol (2002), and Adger *et al.* (2007), are outlined below:

1. Awareness and education on the consequences of SLR and possible adaptations
    a. Is the knowledge available both to institutions and the public? I.e. are the relevant people informed?
    b. Are skilled and trained personnel available?
2. Technological options entailing knowledge in engineering, natural sciences, planning, etc., and a good level of communication and exchange between levels of governance and between neighboring countries
    a. Does the society have the technical means to act?

3. How is the governance quality at central, regional, and local levels?
4. Does the central government have the ability to modify legal framework and implement changes at the local scale, whether it is for Integrated Coastal Zone Management or planning?
    a. What is the quality of knowledge dissemination and communication between different institutional levels? This indicates that the society has the structure and network to facilitate action on climate change.
5. Resources and their distribution
    a. Are there economic means to be able to implement adaptation measures and to do it in a timely fashion?
6. What is the state of human capital, including education?
7. What is the state of social capital, including property rights (intimately linked with quality of governance)?
8. How accessible are risk spreading mechanisms (i.e. insurance, etc.)?
9. What is the state of social infrastructures and equity?

It is important to clarify a subtle but important aspect of adaptive capacity. In order for adaptive capacity to be adequate, each element must be present to a "satisfactory" level. In other words, no element can fully substitute for another. Better education is not a substitute for economic means, and technological options is not a substitute for governance (Tol *et al.* 2008).

4.2.2 Insight into the current state of adaptive capacity in ECA

Taking as an example the water sector in ECA sub-regions, Table 9 provides insight into a range of conditions that may currently help or hinder the development of adaptive capacity in local authorities and central government agencies. The table focuses on those aspects of water management that also affect adaptation strategies in coastal areas.

For what concerns issues of transboundary nature, like the impact of climate change on fisheries, adaptive capacity is adequate in the Baltic Sea, mainly due to the history of collaboration between countries and to the current GEF regional project addressing coastal zone management. In the Black Sea, capacity is low. Fisheries have collapsed in the last decades probably due to overfishing, pollution, and the spread of the exotic species *Mnemiopsis leidyi*. However, the lack of a uniformly accepted method to monitor fish stocks and the ensuing poor data availability means that there is no single accepted scientific result on the causes of the collapse, which makes it harder to frame a strategy of adaptation. The GEF has worked at developing a convention for the management of fisheries in the Black Sea, but the progress between parties halted when Bulgaria and Romania joined the EU. The move subjected the two countries to the Common fishery policy, but Brussels does not have good knowledge of the status of the fisheries in the Black Sea, and at present the situation is stalled (Ivan Zadavsky GEF Staff, personal communication).

In the Black Sea, the only basin currently having good transboundary management and collaboration between countries is the Danube watershed. The International Commission for the

Protection of the Danube River (ICPDR) could therefore have the capacity to deal with the future climate change threats. In terms of control of pollution (as an adaptation strategy), the Commission for the Protection of the Black Sea Against Pollution (2007) is presently struggling, and has limited capacity to monitor and intervene (Ivan Zadavsky GEF Staff, personal communication).

In the Caspian Sea, the level of management and collaboration is represented mainly by the Framework Convention for the Caspian marine environment. 2006 marked a Conference of affiliated parties. Collaboration is well established, but there is concern about future successful implementation of the 4 protocols under preparation: (1) EIA transboundary, (2) Biodiversity, (3) land base sources of pollution, (4) Mutual aid in case of oil spills from shipping (Amy Evans ECA Staff, personal communication).

Table 9 Issues and status of adaptive capacity for the water sector as they relate to adaptation in coastal areas.

Sub-Region	Institutional framework	
	Factors favoring adaptive capacity (+)	Factors hampering adaptive capacity (-)
Central Europe – Baltic Sea – Slovenia	• Baltic: 15 years of cooperation program to reduce pollution loads from municipal and industrial sources • The GEF Baltic Sea Regional Project is addressing safe agricultural practices and coastal zone management.	• Poor cooperation between administrative bodies – must modify legislation to specify responsibilities and functions • Improve capacity at various levels. • Lack of funds recently has hampered the maintenance of flood protection structures.
Southeastern Europe	• Romania and Bulgaria legal water frameworks already in line with EU • Efforts to adapt laws and institutions to the EU water Framework Directive (focus on river basin management)	• Poor effectiveness of managing institutions and legal frameworks
Turkey and Caucasus	• Water institutions are technically strong.	• Water institutions are managerially weak. • Lack of data on the water sector • There exist complex legal issues with water rights, a lack of statutory priorities in the current legal framework – many entities share the responsibility for development, management, and protection of water resources. • Inefficient and sometimes obsolete institutional framework – lack of coordination and several organizations performing the same duties • Need to formulate comprehensive strategies for WRM[22] and bring in different stakeholders
Russian Federation	• Long tradition of integrated river basin management, monitoring of hydrology and weather needs to be fixed after the collapse of the USSR.	• Unsatisfactory safety of dams and other hydraulic infrastructures • Institutional and legal frameworks for sustainable use are in place but implementation is very poor – all the structures need to be potentiated.
Moldova, Belarus, Ukraine	• *Lower Danube Green Corridor* to protect sensitive aquatic ecosystems of Moldova, Ukraine, Bulgaria, Romania • Permit system for water withdrawal – payments for water use (regulation in case of droughts)	• Legal, regulatory, and administrative weaknesses • Need to strengthen institutional capacity in WRM • Poor coordination between various agencies • Lack of a sectored planning approach (rather than at the river basin scale) • Flood control is ineffective and transfers the impacts from upland to lowlands.
Central Asia	• Strong water institutions at the national level	• Water use efficiency is very low (70% of water taken for irrigation is wasted). • Decaying water infrastructure • The five riparian countries of the Caspian Sea dispute the legal status of the sea (this hinders effective tackling of pollution, fisheries, and biodiversity issues).

Key: plus indicates conditions that are promising for adaptation that need to be maintained and updated regularly. Minus indicates conditions that actively hinder adaptive capacity and need major improvements and reforms. Source: Water resources in ECA 2003

[22] WRM = water resources management

4.3 Constraints to developing adaptive capacity

In order to optimize adaptation to climate change in coastal areas we need to work on the spatial and temporal scales of action:

A. Spatial Scale: a water basin approach is needed to tackle sustainably all the various factors affecting coasts, originated by climate change or acting in synergy with it. However, one needs to be concerned about the mismatch between the broad geographical scale (region, watershed, basin, etc.) at which the adaptation strategy is planned, and the local spatial scale at which decision-making for coastal management must be translated into action (Few *et al.* 2004).
B. Temporal scale: the time horizon of local coastal planning is often very short and unsuitable to include considerations of climate change and adaptation strategies.

4.3.1 The spatial scale issue

Strategic coastal management planning is developed principally at the regional and national scale. Policies then need to be transmitted down to local authorities, along with a clear mandate empowering them to adopt a long-term planning strategy that takes climate change into consideration. For this transition to happen, institutional capacity needs to be built both at the national and local scales. This is one of the main challenges that has been hampering the successful implementation of national and supra-national strategies, for instance integrated coastal management (Few *et al.* 2004).

4.3.2 The temporal scale issue

At the local government level there are several constraints to strategic long-term planning:

1. Resources constraints – financial and human
2. Limited mandate of the local planning departments
3. Lack of detailed data on future long-term exposure of the area
4. Technical ability to interpret these projections correctly.

The knowledge and information limitation (number 3 above) originates from the uncertainty surrounding the local magnitude of climate change exposure, and the local sensitivity of the coasts to climatic hazards. The best solution is to first identify all the currently known sources of coastal vulnerability, and then design measures to tackle these issues within an adaptive[23] management framework. In order to do this, decision support tools can be useful, as they guide decision-making in the face of uncertainty.

[23] Here, adaptive is meant in the traditional sense of a set of actions that are designed with two goals in mind: to bring results based on our current knowledge of the system, and to improve the knowledge of how the system works, thereby continuously improving and perfecting the measures of response to climate change.

At the same time, it is necessary to develop a system of scenario projections at the local scale, so that, starting with particularly sensitive areas[24], one knows what the likely exposure will be and how sensitive the "natural protection" (geological features of the coast) is. As noted before, none of this can be achieved without general awareness of the threat of climate change on behalf of planners, decision makers, coastal managers, and the general public (Klein *et al.* 2001).

4.3.3 The uncertainty issue

General uncertainty and the other limitations represent a disincentive for local authorities to embrace long-term planning, and instead reinforce the allocation of resources toward short-term matters.

Uncertainty also complicates the dialogue between decision-makers, private stakeholders, property owners, and the public-at-large. This is especially true when the long-term adaptation measures entail losses of property. In a related matter, it should be kept in mind that in many instances the general public is averse to long-term thinking, and may be unable to put in perspective the proposed solutions. Finally, the "political momentum" toward development that runs contrary to the call for long-term planning and modification of coastal management strategy should not be underestimated.

[24] Sensitive areas may be those with higher interests in terms of biodiversity conservation, urbanization, industry, agriculture, or other activities in place (including tourism).

5. Conclusions

Overall, the coastal areas of ECA basins are vulnerable to climate change. This is mainly a reflection of poor awareness and knowledge of climate change. While some studies have been conducted to determine the risk (exposure x sensitivity) of SLR for various countries, and despite the interest over technical adaptation options, little progress has been made in developing adaptive capacity (Tol *et al.* 2008).

The World Bank can have an important role in disseminating knowledge, building adaptive capacity at the institutional level, and facilitating dialogue between stakeholders by clarifying the trade-offs and risks associated with scenarios of sea-level-rise and climate change. The goal of adaptation is to reduce the vulnerability of a system, but this effort must be integrated within the broader strategy of sustainable development. Adaptation, particularly anticipatory adaptation, must be justified through a balance of costs (damages from climate change) and benefits resulting from the implementation of adaptation measures. The paramount goal is to maintain welfare over time; therefore adaptation is not a measure to be adopted at all costs. In some cases, vulnerability assessment may reveal that the best adaptation is no-adaptation ("wait and see" option). In other cases, major investments may be immediately needed to protect critically valuable assets, while in others still, conditions may allow to stretch investments over long time periods. As also stated by Tol *et al.* (2008), these decisions should be taken within the broader context of multiple stresses affecting the ECA coasts.

Ideally, the whole adaptation process should be undertaken as part of Integrated Coastal Zone Management and/or Integrated River Basin Management frameworks. An Integrated Coastal Zone Management (ICZM) process could provide the framework to perform vulnerability assessment, guide awareness-raising, build adaptive capacity, and select the appropriate adaptation measures.

Several of the coastal adaptation measures recommended by experts are part of the assortment of interventions ordinarily associated with ICZM. Generation and enforcement of zoning schemes, interventions to control erosion, and the development of alternative employment are part of the ICZM arsenal; additionally, they can support those adjustments in spatial planning (protect, accommodate, retreat) that are the center of coastal adaptation.

ICZM can also focus on fostering adaptive capacity in two ways: firstly, by empowering local authorities and developing their resources to embark in a long-term planning effort that includes adaptation strategies (addressing the "temporal scale and spatial scale" issues mentioned in section 4.3), and secondly, by strengthening community organization and promotion of awareness of climate change, both critical to the success of warning systems, which are another important piece of a successful adaptation strategy.

Similarly to ICZM, Integrated River Basin Management (IRBM) has the characteristics to implement adaptation measures to control climate change events affecting coastal areas by targeting issues along watershed. An IRBM project can tackle river planning, water resources management, and flood control measures to control the quantity, seasonal pulses, and quality of water reaching the coasts, while taking into consideration the different uses and stakeholders' needs (agriculture, industry, urban needs).

In ECA, an IRBM to control emission from the Danube has resulted in the reduction of nutrient inputs into the Black Sea. On the other hand, examples of successful ICZM projects are more difficult to find (SDN week 2008; World Bank 2003). Because of the low availability of successful experiences in this area, and considering the uncertainty associated with climatic predictions, a two pronged intervention could be proposed:

1. A process should be initiated to strengthen ICZM plans or kick-start such projects where they are missing.
2. Local-scale projects should be implemented to address adaptation needs at a smaller scale; this is based on the idea that small positive outcomes may build consensus among institutions and the public for the need of a wider approach managed through an ICZM.

In both cases, what is urgently needed is an improvement in vulnerability assessment capabilities. Sensitivity of the coastal environment should be investigated by way of sea-level-rise projections, matched with coastal topographical details, in particular shore types (sand, rocky, etc.) and elevation. In addition, to appraise sensitivity of socioeconomic systems, more precise data should be collected on the socioeconomic relevance of coastal areas. A measure of the overall vulnerability of coasts could then be obtained by overlaying environmental and socioeconomic data with the help of GIS:

- Sea-level-rise projections and coastal topographical and geologic features to provide information on flooding areas based on IPCC climate change scenarios
- Infrastructures (housing, tourism, energy, and transport)
- Land use (agriculture, forestry, etc.)
- Population density
- Location of sources of pollution and other stressors.

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