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# Eu project COASTANCE REPORT

## Component 3

## Regional action strategies for coastal zone adaptation to climate change

**Deliverable 7**

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## PARTNERSHIP

Region of Eastern Macedonia & Thrace (GR) - Lead Partner

Regione Lazio (IT)

Region of Crete (GR)

Département de l'Hérault (FR)

Regione Emilia-Romagna (IT)

Junta de Andalucia (ES)

The Ministry of Communications & Works of Cyprus (CY)

Dubrovnic Neretva County Regional Development Agency (CR)

# TASK B4
# Anticipate the coastal risks : Methods, protocols and practices dedicated to manage submersion and erosion for the end users

## INTRODUCTION

In this Component 3, the COASTANCE partner will look upon the entire set of characteristics that are related to erosion and submersion phenomena in the Mediterranean and thus their work will lead to the development of coherent and applicable tools to quantify the natural hazard, take care of socio economical stakes and anticipate the risks considering the adaptation to climate change. Component 3 focus on the management of the submersion and erosion induced by storms and aims at integrating also the influence of climate changes on these risks in coastal management policies.

## PLAN

1. Understanding about risks
2. Models and tools for risk assessment
3. Contribution to warning system for coastal hazard
4. Vulnerability analysis and risk cartography
5. Scenario storyline and stakeholders participation
6. Help the organization of mitigation and adaptation
7. Recommendations for a better ICZM management

## EU DIRECTIVE

On the 18th January 2006, the European Commission proposed a guideline "regarding flood evaluation and management" which was approved in September 2007 and came into effect in November 2007. This directive aims to improve flood risk management across Europe. It helps Member States by equipping them with suitable tools to reduce the risk of flooding and to limit the impact of floods on human health, the environment and economic activity. It helps Members States to coordinate within cross-border hydrographic basins. The risk management methodology suggested by the directive can be divided into 3 stages:

- The preliminary evaluation of flood risks, which includes namely a description of the hazards and issues for human health, the environment and economic activity in the basin concerned.
- The cartography of flood zones and the susceptible damages caused by the floods. These maps could show 3 scenarios: a flood that returns in 10 years, a flood that returns in 100 years, and an extreme flood. The maps will show the level of water anticipated as well as the speed of the current. The damages will be shown according to 3 indicators: the number of inhabitants potentially affected, the potential economic damages in the area, and the potential damages caused to the environment.
- The carrying out of flood risk management plans, on the level of the hydrographic district. These plans must introduce a global strategy for risk reduction, based on prevention, protection and "organization in critical situations".

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# 1. Understanding about risks

## Estimations of the sea level rise caused by global warming

Climate change will have an increasingly greater, effect on our lives in decades to come, due to its impact on the severity of coastal erosion and the scale of flooding. Numerous climatic impacts, particularly the most detrimental, will be associated with a growing frequency or growing intensity of extreme events. Climate change is characterized by a rising sea level and the modification of the intensity of storms, which will have considerable consequences on the coastal zones of the Mediterranean in the short term.

## What is a storm?

A storm corresponds to the development of an atmospheric disturbance or depression caused by the confrontation of two masses of air both with distinct characteristics (temperature; humidity). This clash engenders a very high gradient of pressure, causing violent winds and most often intense rainfall. We suggest to consider storms were identified using a wave height threshold of 1.5 m, a minimum duration of 6 hours and a minimum gap between events of 3 hours.

The coastline is particularly sensitive to the major risks of erosion and marine submersion. These two hazards are closely linked during a storm at sea, as the increasing height of the water and the energy of the largest waves speed up erosion. Additionally, the retreat of the coastline and the disappearance of the dune belt cause constructions to become vulnerable at the hands of marine submersion. Generally, due to the plurality of their effects (wind, rain, waves) and often wide geographic areas affected, the consequences of storms are frequently serious, as much for human activities as natural environment

## Coastal erosion

The coastal zones of the Mediterranean are continually subjected to altering natural processes, erosion and marine submersions. The impacts of these processes and of these events vary from one coastline to the next and depend on the geological structure of the coastline and its exposure to the impact of waves. With the action of waves and winds; the sand moves along the coastline; known as longshore drift. In a given area, if there is less input at the foot of the sand, erosion takes place. The transfer of sand is permanent, but during storms at sea it can take on significant proportions and lead to irreversible erosion. In order to be able to quantify the erosion (or accretion) of a coast, it is necessary to differentiate input, losses and sediment reserves. The causes of the erosion are :

- A rising sea level : the origins are controversial, (increase in emissions of green house gases?) and its possible acceleration in the years to come will quickly pose problems. Though it cannot be denied that the rise in sea level has and will play a role in the recession of the coastline, it is not completely possible to clearly justify its future intensity and its consequences upon the environment.

- Sedimentary deficit: the using up of available sediment stock is due to the reduction of alluvium contributions from rivers (extraction, dams)
- Settlements: the coastline suffers from considerable issues that are as much economic as environmental. With the emergence of mass tourism 50 years ago, mediterranean coasts underwent significant transformation (tourist resorts, motorways, ports)
- Urbanisation and constructions near the sea: (accentuation of erosion caused by these barriers, insurmountable for sediments)
- Human activity: destabilizing of dune belts (trampled), busy summers, illegal mooring

## Marine Submersion

The hazard of marine submersion takes place when there is a combination of a strong wind and the presence of a depression. In fact, during storms, the intensity of the heaves and the wind, and currents can lead to a tipping of the body of water of the Mediterranean and the breaking of dune belts. It is therefore possible to observe the events of submersion during which water reaches an average altitude of several meters at the seafront.

At the seafront area, the phenomenon can be qualified quickly in comparison to torrential rising flooding. Astern, the rise of the sea, without vigorous effect, again causes a phenomenon comparable to a type of slow flooding. In the areas affected by hazards of coastal erosion and marine submersion, the risks are significant due to the great human pressure and the concentration of activities. The risk of marine submersion is determined by the combination of a rising sea level and the action of the waves. At the proximity of the shoreline, the maximum height of waves is narrowly linked to the depth of the water and the overflow of constructions.

Submersion is linked to the altimetry of the land. The land at the seafront that has an altimetry that is too low is subject to marine submersion as soon as the level of water increases (in case of storm). The level of pools can also rise due to the effect of winds, atmospheric pressure and sea inlets. Similarly then, riverside areas can suffer submersions. The effect of marine erosion can be intensified by the concordance of a river flood linked to heavy rains in the river catchment area. Submersion due to the breaking of dune belt The progressive erosion of dune belts caused by wind or the aggression of heaving provokes the breaking of dune belts. The appearance of breaks in the rope weakens the land situated behind it and no longer offers protection from submersion, thus allowing the water to seep in. Surveillance of the dunes and the location.

# 2. Models and tools for risk assessment

In order to benefit from the most precise estimates possible to model the risks and determine how vulnerable a territory is, it is necessary to have access to a set of accurate and varied data obtained using several types of tools. The partners in the COASTANCE have proposed to use several of these tools in the previous repports

The issues covered, which are of prime importance for our governments, and the partnership that was consolidated around several European projects, so those datas continue to be obtained to enrich the existing observation network. Furthering the actions undertaken to create an European Observatory for the Preservation of the Mediterranean Coasts therefore includes an increased need to acquire data and provide information about the risks of erosion and submersion. We have presented different steps of data in the deliverable 5 (morphologic data, meteorological data, wave climate data...)

## Inspire directive methodology for a common observatory development

(http://inspire.jrc.ec.europa.eu)

The INSPIRE directive came into force on 15 May 2007 and will be implemented in various stages, with full implementation required by 2019. The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organisations and better facilitate public access to spatial information across Europe. A European Spatial Data Infrastructure will assist in policy-making across boundaries. Therefore the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes.

INSPIRE is based on a number of common principles:

- Data should be collected only once and kept where it can be maintained most effectively.
- It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.
- It should be possible for information collected at one level/ scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes.
- Geographic information needed for good governance at all levels should be readily and transparently available.
- Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.

## Coastal Zone managment observatory datas

A good management of the coastal zone and the development of useful tools for administrators require an input of specific data in a form scientifically coherent, which, according to EUROSION, have to focus on:

- Aerial orthophotographs (alternatively, satellite images)
- Historic and actual coastline
- Terrestrial elevation
- Nearshore bathymetry (eventually, offshore bathymetry)
- Cross-shore profiles
- Coastal geomorphology
- Coastal geology
- Seafloor sedimentology
- Sediment transport
- Nearshore waves regime
- Offshore waves and winds regime
- Nearshore currents
- Astronomic tides
- Still water level
- Coastal defence structures

Therefore it would be necessary to localise and collect the available data before integrating them in a system of data organisation and collection. The Geographical Information Systems (GIS) and the databases (and metadata) are useful tools for coastal study, as they allow the storage and use of pieces of information of different nature and origin in the same system.

## The Coastance observatory network

The methodological challenge of this observatory is to represent the principles of integrated coastal zone management (ICZM). It must be multidisciplinary, represented in a spatial and temporal scale clean the coastline and facilitate the integration of various data, including means of treatment and provision of information on natural hazards, socio-economic issues and coastal hazards. And disposal to coastal management of the following functions :

- facilitate dialogue and discussion between the institutions
- capitalize and centralize information studies and existing databases;
- facilitate the sharing and consultation data;
- provide assistance to communicate with those involved the coast;
- confronting coastal thematic data based on a problem;
- have a geographic information system simple to administer and scalable;
- have a permanent coastal atlas.

The observatory, as a tool for decision support, knowledge and partnership with stakeholders is a fundamental tool for the Department and coastal policy. Developments and prospects of such a tool directly address the different needs of coastal and maritime development.

## Pooling of resources for data acquisition

A platform should be create to make sure the data acquisition instruments along the coastline are pooled by a group of research laboratories and public organisations which manage the coastline.

This group have to be involve in fundamental and applied research concerning coastal hydrodynamics and sediment dynamics, coastal engineering, coastal risk, and techniques for coastal protection, management, and planning.

Starting with the acquisition of this data, the scientific questions raised or dealt with by the partners are as follows:

- Identification of catastrophic processes (storms and torrential floods) in the lagunal sedimentary repositories
- Recurrence of extreme incidents on the coastline: Extreme incidents on the coastline are floods and storms. Their combined study in the sedimentary repository is valuable for understanding how the coastline works.
- Risks in the coastal zone : The development of human, economic, and tourist activities means that much is at stake in the coastal zone. Furthermore, given its ocean-continent interface location, the coastal zone is subject to a very distinctive set of uncertainties: submersion, erosion, and contamination.
- Obtaining a good understanding of the uncertainties is a necessary factor if suitable consideration is to be given to coastal risks.
- Characterisation of hydrodynamic processes in the coastal zone (continental slope and plateau) and pre-littoral zone (close to the continental shelf and littoral slope)
- The role of the three-dimensional wave / current combination in pre-littoral hydrodynamics: The term “wave / current combination” refers to the consequence of current effects caused by the wave on circulation (currents caused by the wind, temperature gradients, and salinity), and on the other hand to the effects of circulation currents on the characteristics of the wave.
- Coastal sedimentary processes and the mechanical behaviour of sediments
- Morphological processes in a coastal environment on a granular scale: Sediments deposited in a coastal environment are subjected to various types of stresses linked to surface processes. The relationship between process and stress is being researched.
- Physical and mechanical properties of coastal sediments: In order to study the various surface processes in a coastal environment, it is necessary to have an accurate knowledge of the mechanical and physical properties of sediments on a granular scale.

## Modelisation

Basically, the submersion is a temporary flooding of the sand barrier, lagoons and flood plain by open sea waters due to an anormally high water level in the nearshore zone. The basic parameter that must be considered to quantify the submersion is the altitude of the highest point along the sand barrier. If this point is considered static, the model does not tackle the impact of waves on the sand barrier. if the highest point is supposed to change in elevation, this means that the model may consider the action of waves and other forcings on the sand barrier, as the sea level increases during a storm. However, to compute morphodynamic feed-back on the sea level is not straightforward.

The COASTANCE proposition focuses on the management of the submersion and erosion induced by storms (meteorological control via waves and winds) and does not integrate tsunami (due to the geological control). The aim of this part is to present the methods used in COASTANCE to simulate marine submersions and dune erosion. These two natural processes can be understood by combining all the existing approaches, carrying out a thorough summary of standard engineering methods (analytical and digital models), and developing an innovative and user-friendly digital tool (presentation of the SUBDUNE tool below).

We are working from the assumption that the difference between the altitude of the dune and the maximum water level reached on the beach is a sufficient enough condition to simulate marine submersions. Special attention must be paid to the maximum estimate of the runup on the beach. To do this, we test a recognised run-up estimate formula (Stockdon et al., 2006) and develop a specific digital tool based on recent results.

Next, the various approaches to simulate the retreat and erosion of dunes during storms are tested and criticised using simple equations (Komar, 1999; CEM, 2002 and Van Rijn, 2009) as well as a digital tool (Sbeach, 1989) with a reliable track record.

## Developing a COASTANCE digital tool

Aims and approaches It is a question of creating a digital tool based on physical processes that reproduces the maximum height of the water surface on a beach and compares these results with the semi-empirical engineering models. Both cases will involve using simple input data (wind speed and direction, atmospheric pressure from the open sea, beach slope) that can easily be collected by administrators via websites. The aim is to offer an operational tool that can be quickly accessed during a storm or in case one is forecast.

Engineering approach for estimating the run-up from the open sea Based on a bibliographical summary of coastal engineering (SPM, 1984, Rock Manual, 2009), we have assessed the height of the water level before set-up and to compare the results with measurements from tide gauge tool. Indeed, before estimating the runup on a beach, it is necessary to be able to accurately simulate the water level before set-up. Based on a bibliographical summary of coastal engineering (SPM, 1984, Rock Manual, 2009), we propose to assess the height of the water level before set-up and to compare the results with measurements from the tide gauge tool. Indeed, before estimating the run-up on a beach, it is necessary to be able to accurately simulate the water level before set-up.

# 3. Contribution to warning system development for coastal hazard management

## Early warning system for coastal hazards in Emilia-Romagna including the experimental system developed within the MICORE Project

about WARNING SYSTEM : Here COASTANCE can contribute describing the existing warning system for the Emilia-Romagna coast and applied by the Civil protection (Centro Funzionale) to issue the alert for a coastal event. The system is composed by a wave and an oceanographic model driven by the COSMO-I meteorological model and provide a forecast for the next 3 days of the wave height and wave direction and of the sea level (storm surge). If the thresholds are exceeded an alert is issued by the civil protection. For the test site of Lido di Dante the system is completed by a morphodinamical model (x-beach) actually under test implemented and calibrated during the Micore project. The x-beach outputs include wave run up, water level and beach profiles during the storm. In principle the results of the x-beach model could be compared with the output from the model developed by the coastance project. The input data needed to run the coastance model are available for the Emilia Romagna test site. This part describes the organization and the methods applied by the Italian and Emilia-Romagna's Civil Protection System to forecast and manage the risk of submersion of the coastal areas. The report is focused on the new civil protection schemes designed to improve the early warning system for the coastal alert. These new schemes start from the prototype of a warning system developed in Emilia-Romagna by the FP7 European funded project MICORE (Morphological Impacts and COastal Risks induced by Extreme storm events). The goal of the new scheme is to take into account coastal risk as a Civil Protection issue, considering the new technologies (such as numerical models and informative systems) that allow to forecast the key drivers of the Submersion hazard (i.e. Storm surges and storm waves ) and their impact on the coast. (see the report "TASK A-2: identificazione dei processi guida in considerazione dei fattori sociali, economici, politici, ambientali e dei cambiamenti cliamtici" for a full description of the key drivers and indicators for the coastal risk). The numerical models to forecast submersion, and informative systems, are described in the section "Models and tools " of this report. Some of these new technologies, such as the X-Beach model, were improved and/or developed and tested, during the MICORE project.

## The WEATHER WARNING for coastal event

The major innovation that has been introduced in the weather warning protocol is the identification of thresholds. Studies based on historical meteo-marine datasets have shown that coastal risk depends more from the total water level than the height of waves breaking on the shore (Armaroli et al., in press; Perini et al., 2011), the worst condition is for sure the simultaneous combination of the two phenomena. Three classes of threshold values have been identified, one class considers only waves, another considers only sea level and the last considers the combination of both. Therefore the trigger for the warning issue and the activation of the alert procedure is the exceeding of these identified thresholds, listed in Table below, of the sea-level elevation (surge), wave height and/or their combination. When one or more of the above thresholds are exceeded according to the outputs of the surge and wave operational models, the HydroMeteoClimate Service (ARPA-SIMC) issues a weather warning for a coastal event (avviso meteo per evento costiero in the document). A new format for the weather warning for the coastal event containing a specific section for coastal hazards (Evento costiero) is now under test by the CF of the Emilia-Romagna region. The new format divide the coast in four macro-areas. Each macro-area is identified by the administrative boundaries of the four provinces that face the sea (from north to south: the province of Ferrara, Ravenna, Forlì-Cesena and Rimini).The coastal hazard section provides information on the forecasted meteo-marine conditions for each of the four macro-areas. Information on the magnitude of the wave height and water level are given also through the definition of their return period (1-in-1, 1-in-10 or 1-in-100 year); furthermore the occurrence at the same time of a high water level and a significant wave height is underlined and the predicted duration of the combined effect of surge and waves on the coast is indicated.

## The EARLY WARNING for coastal risk

As a consequence of the meteorological warning, the regional task force evaluates the reliability of the data presented and takes decisions and actions to prevent hazards to people and structures placed along the coast. The task force is composed of experienced technicians of the Geological Survey, ARPA-SIMC and Civil Protection, which meet up daily to evaluate the weather and sea models forecasts. In the new scheme the technicians, during the daily briefing, can discuss a wider set of information and data deriving from the combination of the static hazard maps (to determine if an area is vulnerable to certain conditions), the weather and sea state forecast and the morphological model outputs. They consult also on the results of the historical storm catalogue that give important indications on coastal hot spots.

## The CIVIL PROTECTION ALERT for coastal risk

All the information contained in the documents described in the above paragraphs will be synthesized by the regional Civil Protection Agency into a civil protection alert for coastal risk. The format will be similar to the existing one and a specific section for the coastal hazard will be added. In this section information provided by the weather warning and by the early warning will be summarized. The section of this official document describing the actions that should be taken by the authorities and operational structures and the recommendations issued to the general population for the prevention and mitigation of the effects of marine storms on the coast is of primary importance. These recommendations include advising managers of the bathing establishments, lifeguards and Port Authority to warn people of the expected danger, including the use of dedicated beach signage.

# 4. Vulnerability analysis and risk cartography

## Definition of vulnerability

The combination of these "natural" and "anthropogenic" vulnerabilities allows us to obtain the global vulnerability of the sector. The reason for this is based on the interlocking of scales, a list of relatively precise issue descriptors describes a more global issue, which incorporated with other issues, allows for the definition of vulnerability, first by theme and then in a global manner. The issue descriptors, as explained in the presentation of socio-economic issues, each have an attributed value. All of these values allow the issue descriptors to obtain the total value of an issue and thus to define the importance of this issue for a given sector. Similarly, some value classes will be attributed to descriptors for the elements of the area (marine weather forcing and morphology and sediments). The sum of these descriptor values will thus allow us to obtain a global value for each of these factors. It must be specified that the regulations regarding risks do not intervene in the definition of vulnerability. In fact, whether or not a commune is covered by a Risk Prevention Plan does not influence its real vulnerability. It is for this reason that this type of regulation is not taken into account in the issue grids. Nevertheless, once the vulnerability cartographies are established; they will be put beside the regulatory information, i.e. Risk Prevention Plans, in order to check the coherence between regulations in place today and the vulnerability result. Following this, the vulnerabilities will themselves be quantified by the sum of the issue values and the elements of the area that determine them. The sum of these different vulnerability values will produce the value of socio-economic vulnerability, and the vulnerability of the area. However, it has been established that following this there is likely to be a balancing of these two vulnerabilities in order to obtain a global vulnerability that combines socio-economic and area aspects, but in a way that prioritizes socio-economic vulnerability. This vulnerability incorporates particularly noteworthy issues, especially concerning human safety, and it therefore seems preferable to highlight its importance. Thus there will be a balancing of 60% for socio-economic vulnerability and 40% for area vulnerability. All of the global vulnerabilities will then be mapped out in order to obtain a document that allows us to compare the differences in vulnerability according to different sectors, and to identify the factors (human, economic, regarding infrastructures...etc) explaining this vulnerability. We will therefore obtain an identity card of the sector's vulnerability.

## The evaluation of the risk

A method for the evaluation of the sea storm risk will be used at the regional scale. The applied method allows the definition of the vulnerability (V) and the risk (R) through the creation of a territorial database and simple calculation procedures; it may be a valid support to optimise the participation strategies because it is based on objective and univocal criteria for the classification of littoral stretches and also because it provides scenarios useful in the ICZM. A specific “informative level” provides scenarios of coastal submersion related to the recurrence of extreme events and to the forecasts of a sea level rise at the year 2100.

## Analysis of the submersion risk

The proposed method is based on the parameterisation of the submersion trend of the coast and on the evaluation of its spatial distribution through the identification of similar sector. The submersion trend or the vulnerability may be synthesised by the use of indexes; in particular the real vulnerability is the interaction of :

> index of potential vulnerability that describes the geo-morphological, sedimentological and anthropic trends to the submersion, considering the littoral unprotected;

> index of efficiency of the defences (IED) that corresponds to the passive efficiency of the coastal structures (natural and artificial) to the submersion.

## Subdivision of the coast in homogeneous stretches

A delicate step for the risk definition consists in the subdivision of the coast in sufficiently homogeneous stretches in which the submersion trend can be considered a constant. The approach used in the present study is semi-quantitative. A first subdivision may be done in correspondence with the harbours jetties and the principal fluvial mouths. Successively the subdivision is based on the extension of the defence structures since they condition the natural evolution of the coast. A multidimensional procedure may also be applied. It consists in a Principal Components analysis, followed by a Cluster one, in order to obtain a more effective subdivision in homogeneous stretches, considering the large number of environmental and human parameters taken in consideration.

## Identification of the environmental parameters

The criterion to identify the coastal zones more vulnerable to the marine ingression is based on an objective evaluation of the characteristics of the different coastal stretches, represented by a set of variables related to 5 compartments, which constitute the base for a zoning of the littoral, expressed in terms of vulnerability.

1. Marine weather conditions
2. Geological-morphological conditions and pressure of use of the beaches:

- shoreface width

- emerged beach width
- emerged beach height
- mean diameter of the sediments
- pressure of the use of the beach

### 3. Evolutive trend of the beach
- shoreline evolution (recent / historical)
- shoreface evolution

### 4. Subsidence of the coastal territory

### 5. Typology of the defence structures along the coast and in the hinterland:
- Soft protection
- Rigid protection: marine structures, adherent structures and hinterland structures.

The weather conditions have a significant influence on hazard. For such reason, the occurrence of flooding events at medium-long term period and the extension of the flooded inland will be estimated through a mathematical model considering the wave climate data and the geometry of the shoreface. The results will be useful for the risk assessment and especially for the identification of the zones at risk. The geological-morphological parameters and the pressure of the beach use characterise the beach system in terms of accommodation and mitigation capacity against the submersion. The trend provides an evaluation of the beach system behaviour for a short and long term period. The subsidence enhances the phenomenon of the coastal submersion. Finally the different typologies of structures identify the passive mitigation answer of the beach to the submersion.

## Calculation of the "potential" vulnerability
The potential vulnerability (Vp) represents the vulnerability of the littoral when considering any defence structures (natural and/or anthropic) against marine ingression. The variables used for the calculation of Vp are: 1) width of the emerged beach, 2) height of the emerged beach, 3) width of the submerged beach ('till the closure depth), 4) recent evolution of the shoreline, 5) historical evolution of the shoreline, 6) shoreface evolution, 7) subsidence, 8) mean diameter of the beach sediments and 9) pressure of use.

The codified value of the variables is obtained by means of evaluating opportune classes of values, established in consideration of the characteristics of the examined littoral. Therefore a ponderal weight related to its importance for the mitigation of the risk is assigned to each variable. The weight is defined according to the characteristics and the particularity of the littoral.

## Calculation of the "real" vulnerability
The real vulnerability Vr represents the vulnerability of the littoral, mitigated by the natural and artificial defences. The mitigation action of the

defences is evaluated through an Efficiency Index
(Di) related to the anthropic defences and the natural dunes.

The efficiency of each defence structure is represented by:
d = original value of the class of the structure, Vpmax = theorical maximal potential vulnerability, emax = maximal class of efficiency relative to the structure, Vpmax/emax = coefficient of normalisation of the values related to the structures

A special index, the Efficiency and Stability Index (IES), is determined for the natural dunes according to the height of the crest, the rate between the dune height and the width of its marine side, the linear continuity, the conservation state and the vegetal cover. The calculation of IES is given by:
n
V
IES i S = Vi = variables related to the dunes; n = sum of the maximum values attributed to the variables (used to normalise the index in the range 0-1)

The total efficiency of the structures is: IED = IES + Di
Vr may be therefore calculated as: Vr = Vp – IED

## Calculation of the submersion risk

The analysis of the Risk (R) is evaluated according the following relation:
R = Vr .E
Vr = real Vulnerability, E = economical value of the littoral

The Economical value (E) is an evaluation of the social, economical, natural value of the exposed zones or the cost in monetary terms of the direct and/or indirect impacts. Because the procedure for an economical evaluation is complex, a rapid and effective methodological approach is used to determine E, based on the coastal territory's land-use.

## Storage modality of the parameters

The database is realised in order to be easily updated. The database is structured according to the parameters (variables) used for the definition of the risk. The structure of the GIS could be realised in the ESRI(r) Arcgis environment for the management and analysis of the data and for the creation of the thematic cartography.

The geographical definition of each stretch is defined through the Universal Transverse of Mercator projection system and the geocentric Datum WGS 84. The aerial images "Volo Italia" 1998/99 (IT2000) are used as topographical base.

## Restitution modality of the territorial data : the thematic cartography

The representation of the results consists in a chart where the morphological and sedimentological parameters, the land use and the defence structures are represented with non-conventional symbols. A territorial informative level, resulting from the analysis of the impacts of the submersion scenarios at short, medium and long term, will provide (in phase B) an estimation of their incidence on the socio-economical pattern of the coastal zone.

These scenarios, based on models of the extreme wave height on the coast, will be elaborated for each homogeneous stretch in order to "quantify" the coastal potential criticism for specific "morpho- types". At long-term the sea level rise represents the climatic factor used for the evaluation of the submersion phenomenon. A "multi-scenario" approach will evaluate the potential incidence of more sea level rise scenarios on the coastal zone, considering the climatic (global) and geological (local or regional) causes of the phenomenon.

## Tools for evaluate risks resulting from natural hazard and human stake

Most important tools needful in order to realize vulnerability and risk cartography are Geographic Information systems ad coastal modelling and monitoring networks (including remote sensing). Geographical Information Systems (GIS) are tools facilitating the reporting, management and exchange of territorial data and, as such, are indispensable to spatial planning and integrated coastal zone management. This form of good practice is already widespread in risk analysis. The GIS can be improved by building thematic databanks of different fields developed on a territorial scale. The European Union has addressed this topic by providing operative tools such as the GIS database for European coasts (scale 1:100,000) and guidelines for the "implementation of local information systems for coastal erosion management" which were released by the European Commission's Environment Directorate- General as part of the EUROSION programme and published in 2004 (European Commission, 2004). These guidelines were acknowledge in order to develop the regional Coast and Marine Information system. A main tool to realize risk maps and assess the impact of climate change is coastal modelling. The modelling should reproduce.

both the short term processes (i.e. short range forecast and near real time analysis) and long term processes (i.e. climatic models). The short range models are run daily to analyze and forecast wave storms and storm surges impacting coastal zones. The impact of the storm on the coastal morphology and the risk of coastal submersion and erosion are modelled by a morphodynamic model simulating the loss of sand, the dune erosion and the submersion / overwashing.

The climatic models are applied to assess future scenarios related to climate change. There is a strong need to improve the capability of climate models to simulate the climate change at regional and local scale

The monitoring network is a basic tool that must be maintained and continuously improved in order to calibrate and validate coastal models.

## Define the most appropriate indicators

An ICZM indicator is the concrete expression of a coastal analysis criterion, an observable or quantifiable indication likely to respond to a given problem. An identical analysis criterion can give rise to several indicators that combine. The relevance of these indicators depends on the availability and the quality of gross or processed data used for their conception. These indicators that we display further are essential for the development of a map showing risk coverage thanks to their concrete aspect. They are easily readable in a database management system and they are transposable in a geographic information system: two systems which, for the ICZM, constitute

## Production of map

Most important tools needful in order to realize vulnerability and risk cartography are Geographic Information
systems ad coastal modelling and monitoring networks (including remote sensing).

Geographical Information Systems (GIS) are tools facilitating the reporting, management and exchange of territorial data and, as such, are indispensable to spatial planning and integrated coastal
zone management. This form of good practice is already widespread in risk analysis. The GIS can be improved by building thematic databanks of different fields developed on a territorial scale.

The European Union has addressed this topic by providing operative tools such as the GIS database for European coasts (scale 1:100,000) and guidelines for the “implementation of local information systems for coastal erosion management” which were released by the European Commission’s Environment Directorate- General as part of the EUROSION programme and published in 2004 (European Commission, 2004). These guidelines were acknowledge in order to develop the regional Coast and Marine Information system.

A main tool to realize risk maps and assess the impact of climate change is coastal modelling. The modelling should reproduce both the short term processes (i.e. short range forecast and near real time analysis) and long term processes (i.e. climatic models) The short range models are run daily to analyze and forecast wave storms and storm surges impacting coastal zones. The impact of the storm on the coastal morphology and the risk of coastal submersion and erosion are modelled by a morphodynamic model simulating the loss of sand, the dune erosion and the submersion/overwashing. The climatic models are applied to assess future scenarios related to climate change. There is a strong need to improve the capability of climate models to simulate the climate change at regional and local scale. The monitoring network is a basic tool that must be maintained and continuously improved in order to calibrate and validate coastal models. In this first phase of study, one of the objectives is to define the indicators of issues. Studying the issues in this way will allow for the anticipation of the settlement of this area and will avoid worsening the vulnerability in the principal settlement tools; this work should be considered as an instrument that aids decisionmaking:

Each actor should be aware of the global nature of the phenomena at stake and agree to act in a coherent whole. Fighting against natural phenomena of this nature will generate follow-up and very significant intervention discussions. It is therefore necessary to clearly determine these issues in order to determine the sectors that need protecting at all costs to concentrate resources and, in other sectors; to prioritize cooperation leading namely to the adaptation of uses to a natural development or the restoration of a natural function (EID, 2006). However, the definition of the issues does not allow for the consideration of the vulnerability of a sector in its entirety. Thus for the area of vulnerability; in which the analysis of environmental issues intervenes, it is necessary to integrate a characterization of marine weather forcing, of morphology and sediments. These elements do not constitute issues but they are affected by the hazards of erosion and submersion. They should therefore be integrated in global vulnerability.

# 5. Scenario storyline and stakeholders participation

## The COASTANCE 7-STEP Methodology

### 1) Compilation of environmental information of selected coastal zones and review of previous foresight studies related to the dynamic of these areas.

Compiling environmental information is the first step for the foresight analysis. Quantitative and qualitative data are gathered in order to have an overview of the whole coastal system, including both terrestrial and marine domain, as well as bio-physical, socio-economic and policy data. Additionally, previous studies regarding the dynamics of the area of study are compiled.

### 2) Analysis and characterisation of current situation and mainstream trends- Writing provocative reports for stakeholders' consideration.

After compiling environmental information, mainstream trends are identified based on the data gathered. Mainstream trends can be referred to demographic, economic, political, cultural or physical changes within the area of study. Identifying mainstream trends is necessary to elaborate provocative reports for stakeholders' consideration. These reports are conceived to facilitate stakeholders' involvement in Step 4: drivers' identification.

### 3) Identification of relevant stakeholders in each case study.

To ensure the success of the scenario exercise, it is indispensable to identify all stakeholders in the area. These stakeholders include communities, public entities concerned, economic operators, non-governmental organizations, associations and any other social actor related to the coastal area. The method to identify stakeholders may be chosen taking into account both the spatial scale of the study and the resources available.

### 4) Identification of key drivers.

"Drivers" or "driving forces" are any natural or human induced factor that directly or indirectly cause a change in a system (WRI, IUCN and WB, 2005). In scenario studies, drivers' identification help to spot the main forces implicated in the process of change, thus, to elaborate possible futures. Drivers can be identified both by participatory or non-participatory methods, in COASTANCE Future Scenarios both approaches are integrated.

### 5) Selection and construction of possible scenarios to represent.

COASTANCE Future Scenarios are built combining the involvement of an expert group and the stakeholders. As a result of a deliberative process and using a matrix approach, four different and alternative scenarios are created. In each scenario assumptions are made regarding the internal driving forces and its consequences, taking into account that each of the scenarios must be plausible and contrasted with stakeholders.

### 6) Drawing narrative storylines for future scenarios considering possible effects and consequences in the studied zones.

Storylines are compelling stories about the future in a narrative way. Storylines, is central to the process and plays a pivotal role in engaging participants in a scenario analysis exercise (Frittaion et al, 2010). Storylines are developed with qualitative information and then underpinned with quantitative information where appropriate. While it is possible to develop any number of stories about how the future may play out, the art of scenario-building is to choose those stories that shed the greatest light on the issue under consideration (Schwartz, 1996).

### 7) Extracting strategies and recommendations to face the future.

Scenario planning is a valuable tool for enhancing the "robustness" of strategies, that is, their viability under different conditions. Scenario studies can be used to examine a strategy within any conceivable future environment, thereby reducing risk by discriminating between strong and highly contingent strategies (Heugens, 2001). COASTANCE Future Scenarios will provide a helpful tool to elaborate strategies and recommendations for better management of coastal natural and anthropogenic risks in the Mediterranean Region.

## Types of scenarios which can be used:

- Exploratory or forecasting scenarios VS prescriptive, anticipatory or backcasting scenarios. Exploratory or forecasting scenarios take the present as their starting point and envision alternative paths into the future. While prescriptive, anticipatory or backcasting scenarios begin with the identification of a particular future situation and then trace its origins and lines of development back to the present.
- Qualitative VS quantitative scenarios: qualitative scenarios are based on stories and narrative, and quantitative scenarios rely on models. Lately mixed scenarios-qualitative & quantitativeare becoming increasingly popular among researchers.
- Short-term scenarios Vs Long-term scenarios: Whether a study takes a short or long-term view significantly depends on the context of study. However, as a general rule a longterm scale for a scenario is 25 years or more whereas a shortterm scale is 3-10 years
- Local scenarios VS Global scenarios: Scenarios can be developed according to different geographical or spatial scales, ranging from the global scale to supranational areas, to national, to sub-national or regional areas, and finally to local areas (EEA and ICIS, 2000).
- Business-as-usual Scenario VS Alternative Scenarios. Business as usual (BAU) scenario is a further development of present conditions (O'Riordan et al., 1993) whereas alternative scenarios explore more unconventional or unusual future possibilities.

After explaining the nature, characteristics and different types of scenarios, it is interesting to point out why scenarios are helpful in decision-making and policy-design. We live in an extremely unpredictable world, where changes occur increasingly faster and at the global scale. Thus, present times require making decisions in a context of great uncertainty, in which the capability of adapting to changes is a strategic factor. In this era of globalisation and uncertainty, scenarios studies are specially useful because they: take into account the complexity of the changes, express different versions of the future, create options where the future is unclear, broadens the perspective of decision-makers and facilitates the development of plans which improve the response capacity to new challenges. In addition, the generation and exploration of possible scenarios help institutions and society being prepared for future. In this sense for the scenario method it is essential to involve all stakeholders who have the capacity to affect the system. During the scenario-making process stakeholders consider both present problems and future options, and also the consequences associated to their decisions. Thus, the mere exercise of scenario analysis is an achievement in itself and prepares the system to cope with future and possible changes.

## COASTANCE Future Scenarios

COASTANCE Future Scenarios are based in three main characteristics. First, they are explorative scenarios, thus, they are an helpful tool for asking "what if" questions to explore the consequences of uncertainty.

By working with scenarios under an explorative approach, the analytical focus is shifted away from trying to estimate what is most likely to occur toward questions of what are the consequences and most appropriate responses under different circumstances (Duinker and Greig, 2007). Second, COASTANCE Future Scenarios are based on storylines, which are brief narratives that link, in a plausible way, historical and present events with hypothetical future events. The storyline approach is a powerful and flexible instrument that can easily be adapted according to the needs of the project (Postma, et al, 1995). And, third, future scenarios will be built based on a participatory process where stakeholders play a key role. Discussing scenarios with local stakeholders is thus a promising way to contribute to integrative and broadly accepted planning and policies (Soliva et al, 2008). A participatory approach for scenarios development is highly valuable due to the following reasons (Welp et al., 2006; Kok et al., 2006; Pahl-Wostl, 2002; van Asselt and Rijkens- Klomp, 2002) :

- Give access to practical knowledge and experience, learn about new problem perceptions and identify new challenging questions.
- Bridge gaps between the scientific communities and governments, businesses, interest groups or citizen, thus providing a reality check for research assumptions and methodology.
- Improve communication between scientists and stakeholders and facilitate collaboration and consensus-building on problem- solving.
- Increase the salience and legitimacy of the scenario and thus the acceptance among end-users.

Another interesting charasteristic of COASTANCE Future Scenarios is that, attending to the nature of the project, especial attention is given to coastal risks and its effects (erosion, flooding, sedimentation, submersion, etc.) and global change processes. In addition, scenarios are being generated using a long-term perspective, taking as horizon the year 2050. Finally, the result of applying the scenario method in COASTANCE may be the input for simulation models. These models will allow to make predictions on the future development of systems (or subsystems) under a number of assumptions established in the defined scenarios.

## Guidelines for Scenarios

The Guidelines for COASTANCE Future Scenarios aim to be a didactic tool that will allow the replication of the methodology for future scenarios in any other Mediterranean coastal site. In the guidelines the seven steps of the methodology (presented in Section 2) will be explained in detail providing bibliographic references and examples from the study site in Andalusia (information about the study site can be consulted on Box 1). Up to now, the first working phase for future scenarios, which include steps 1, 2, 3 and 4, has been developed and tested in the study site with valuable results. Part I of the Guidelines for COASTANCE Future Scenarios include the work developed up to now, from Step 1 to Step 4, whereas the remaining steps of the methodology (Steps 5, 6 and 7) will be presented in further deliverables.

Complexity in physical terms. The coast of Ayamonte is particularly dynamic due to its location in Guadiana estuary, where the mixture of marine and riverine waters originate complex chemical and physical processes. The morphology of the shoreline is composed by barrier islands, beaches, dunes, marshes and riverbanks. Due to the variety of habitats, Ayamonte has a high biodiversity, specially regarding birds (some areas are under protection). Coastal dynamics in Ayamonte has been modified by strong human actions over the last decades (construction of breakwaters and dams, urbanization, destruction of the dune barrier, etc.). These actions have altered the natural dynamics, and nowadays Ayamonte's coast is highly unpredictable, thus its management is a hard and challenging task.

Complexity in socio-economic terms. Ayamonte has traditionally developed relying on activities such as fishing, trade, canning industry, and recently, aquaculture. However, these activities are currently in second place because new and powerful engines have appeared: sun and beach tourism and building sector. Both sectors have developed on a highly dynamic physical environment, generating strong environmental (and social) impacts.

Complexity in administrative terms: Ayamonte is located on the border with Portugal, with the Guadiana river creating a natural frontier between both countries. The management of the river is shared between the two countries, and therefore it is highly complicated. Improving institutional communication and collaboration between the two administrations is necessary for the proper management of their resources.

# 6. Help the organization of mitigation and adaptation

### Adaptation

Process, action or result in a system, such as a sector, region or country, which tends to permit to this system to treat or manage in a better way changing conditions, stress, dangers, risks and opportunities. These changing conditions could be for example climate stimuli, their effects or impacts.

### Cooperation :

Cooperation is a process that enables at different people to agreeing a common project. It prepares a decision, but without obtaining it necessarily.

## Linking scenarios with coastal risks and climate change

The risks to human populations in coastal areas are changing due to climate and socio-economic changes, and these trends are likely to accelerate during the 21st Century (Dawson et al, 2007). Assessing climate-change impacts requires not just considering climate in isolation, but other linked changes and stresses, including both environmental and socio-economic trends. The factors that influence particular impacts and vulnerabilities are likely to be widely variable, and may include demographic, economic, technological, institutional, and cultural characteristics. For instance, socio-economic and demographic trends often imply growth in flood and erosion risk areas, compounding the increase in risk due to climate change (Dawson et at, 2008)

Socio-economic scenarios facilitate integrated analyses and assessment of mitigation, adaptation and residual climate impacts and associated costs, risks and benefits and they help to frame local analysis (Carter, 2010). But generating alternative scenarios for the future society can launch questions as: Which scenarios are more vulnerable? Which kind of adaptation measures will have to be taken in each scenario under specific risks? Which decisions can we take now to reduce our tomorrow's vulnerability? All these questions can support a deliberative process and consensus building between stakeholders and can provide some light in the decision making process. Even if the reality will not correspond to any of the scenarios, they allow decision-makers to think strategically and to decide to which direction we want to change our path.

Both the general literature and the results presented in this project sustain that scenarios are an ideal tool for decision making and planning in coastal areas in the context of climate change. In addition they facilitate the communication of future risks to communities. This last application of the scenarios has a huge potential for approaching the scientific community to the society in the field of coastal risks.

## Conclusions extracted from the use of scenarios

The experience developed in Component 3, up to deliverable 3, of the COASTANCE project shows that scenarios are a powerful tool for coastal planning. The main findings are summarized below:

### Scenarios for Policy-making

• The benefit of scenarios lies in the ability to compare competing viewpoints within a single framework, thus allowing policies to be designed in a more robust manner.

• The motivation for using scenarios is that they allow focusing in the consequences of changes and most appropriate responses under different circumstances, helping to identify the most adequate policies.

• Exploring and identifying the uncertainties over such factors becomes critical in order to formulate "least regret" strategies that, given the uncertainty, produce the fewest drawbacks, if not the greatest benefits.

### Scenarios for Communication

• Scenarios stimulate strategic thinking, creativity and communication. It is a tool for allowing individuals and organizations to 'create their own future'.

• Scenario development tends to facilitate better communication between actors in decision-making processes and increases an appreciation of the differences in stakeholder concerns and perspectives.
• Scenarios attempt to make understandable what is essentially abstract and difficult to represent in the imagination.

### Scenarios for Society Engagement

• Scenario enhances stakeholders' involvement from the beginning to the end of the process and provides an opportunity to understand public's different opinions on relevant and critical problems on coastal areas.
• Scenario-based approaches are an effective way of engaging actors who might otherwise be unresponsive to scientific information presented in more traditional forms such as scientific articles or reports.
• These social learning methods can provide immense saliency and richness to scenarios and become a vehicle for consensus building and problem solving.

## Scenarios for Coastal Risks and Climate Change

• In the light of the risks and uncertainties coming from climate change, it is necessary to use innovative tools that integrate all the dimensions of change; scenarios are unique instruments in achieving this goal.
• To understand the coastal risks and the resulting choices and pathways to successful management and adaptation, prospective assessments are essential.
• Socio-economic scenarios facilitate integrated analyses of mitigation, adaptation and climate impacts and associated costs, risks and benefits and they help to frame local analysis.
Based upon all these findings it can be conclude that scenarios are a powerful and innovative tool for coastal planning in the current context of climate change and associated risks. Scenarios, based on an integrated approach and governance principles, coincide with the principles promote by COASTANCE project and in a broader sense, with the European Union approach to coastal management and planning. In the light of the results obtained, further use and promotion of scenarios in the Mediterranean coastal areas is encouraged, both at local and regional scales.

## Adaptation challenges

Climate change is a phenomenon acknowledged by the scientific community and the work carried out by the IPCC (Intergovernmental Panel

on Climate Change) enables us to assess the changes we are currently experiencing and anticipate the effects of climate change by the turn of the century according to various scenarios. Its foreseeable effects in terms of natural risks are more difficult to assess, but the current status of scientific knowledge will be presented from two perspectives, namely the impact climate change could have on the coastline and current avenues of research and how natural risks to the coastline and protection systems could evolve to adapt to climate change.
In view of sustainable development, and very generally, the adaptation scenarios we propose should take account of:

• geographical, social, sanitary and ecological inequalities
• evolution in governance, training and information processes,
• medium and long-term time scales,
• strong solidarity challenges (rich/poor, North/South, Local/Global, man-nature, but also intergenerational solidarity by taking account of future generations in law and land planning).
• Collaborative and inclusive work processes and transfer of knowledge and know-how, could facilitate the writing, implementation and updating of the adaptation sections of the climate plans.
• Numerous processes, better share and more anticipative of environment management, crisis management, victim assistance and in particular management of water, soil and food or energy resources, are among the major challenges of the 21st century.
• The issue of shared reserves (food, land, water, seed, etc.) is also raised, specifically under the aegis of the UN.

Adaptation should be defined according to the vulnerability of the territory and, in particular according to biogeographic factors, infrastructures and the vulnerabilities specific to local stakeholders. This is delicate work due to the fact that there are considerable margins of uncertainty in time and geography in terms of climate prospective. Also, it is difficult to adapt the precautionary principle to coastal development.

Some adaptation strategies will probably remain theoretical as they are based on precaution, in a field where prospective relies on probability scenarios and not on absolute certainties, including as to the extent, costs and location of the expected consequences, highly variable according to the scenarios taken. Finally, the potential of adaptation for human and ecological systems is very unequal between regions and economic contexts. The ability to adapt is closely linked to social and economic development (IPCC 2007) of the territory.

## “Climate Plans” including an Adaptation section

Adaptation is now one of the sections in “climate” plans, in an approach to reduce and manage risks and damage, prepared and implemented by local authorities, companies and individuals. We are trying to model the future, but some stakeholders may also benefit from possible retrospective studies (e.g.: climate warming already affected Europe and part of the globe during the 7th century, forcing some of the population to move back from the sea (in zones corresponding to the current Netherlands, part of Belgium and French maritime Flanders), and prospective studies to try to anticipate the effects of the expected climate change, in particular linked to the anthropogenic exacerbation of the greenhouse effect which could lead to an increase of 2°C or more by 2100.

In particular, the aim is to better prepare (transition) or suffer less an increase and aggravation of the frequency and/or intensity of events such as increase in average temperatures, storms, rise in sea levels, with the effect of less efficiency of dykes and heavy-duty protections and probable aggravation of coastline erosion and of course, sea submersions.

## To be taken into secondary account as part of an IMCZ approach

## Europe distinguishes two types of measures:

• low-cost measures (conservation of water resources, evolution in ecological engineering, strategic realignment, public planning and awareness. Some of these adaptation measures are known as "no regret" measures, i.e. they are profitable and useful in themselves, whatever the extent of the warming and would still be so today, without taking climate change into account. Adaptation in some regions also consists of promoting a few possible benefits of warming (longer tourist season, some crops would benefit from a longer growing period).

• the most costly measures, protection (dykes, dams, pumps) and relocation (ports, housing estates, villages or towns, commercial zones), for example the Dutch are experimenting with floating housing and a "floating" quarter. Beach nourishment is a measure that is also increasing in cost given the exponential rise in natural phenomena at the origin of erosion and submersion. However, when the stakes cannot be moved, this is the best possible alternative.

## Society's methods of adaptation

Beyond our issue focused above all on managing erosion and submersion, they concern property, services, the environment and people. Various strategies are possible and complementary, to adapt our built-up and cultivated environment so that it better resists the expected or potential climate events, and for preventive adaptation for people and systems (individual and collective), the partly uncertain changes (meaning a change in behaviour or even in society).

## Among the strategies already proven or in preparation are:

• "Small step" adaptation strategies, i.e. as and when unforeseen climate events occur,
• "Large step" adaptation strategies, or on the contrary, major projects or framework laws, a state, region or major local authorities impose preventive adaptation of land planning and management;

• Strategies with several open options, based on prospective scenarios;
• Integrating strategies which try to focus on elements of ecological, economic, societal, health resilience, etc.
• Implementation of risk management and insurance tools, possible with provisions;
• Implementation of resource management tools (land, water, fish, forest, etc.);
• Implementation of land solidarity (for example as part of a SDAGE for water, in Europe), but faced with extensive risks (sea submersion for example), this solidarity is rapidly limited today, as shown in the unresolved issue of the status of climate refugees;
• Adaptation of expected climate conditions and to extreme weather events.
• Adaptation of subvention methods (ecocompatibility, ecotaxes, etc.) and standards and regulations governing land planning and construction;
• Implementation of cultures or animal breeding that is more drought or salt-tolerant (e.g.: salt prairies)
• Forestry management that restores conditions for better resilience to storms, diseases, parasites and fires;
• Biological corridors, in green belts, to help species migrate to climate zones enabling them to survive and migrate naturally.

# 7. Recommendations for a better ICZM management

## ICZM and Governance

During the last decades there have been deep changes on coastal areas: agriculture intensification, urbanisation or infrastructure developments have left their print on the landscape. Human influence in the coastal zone has turned coastal erosion from a natural phenomenon into a problem of growing intensity; humaninduced factors are present in many cases and they operate on the morphological development of the coastal area as well (European Commission, 2004). Climate change might become an important factor soon, and its associated effects (sea level rising, extreme storm events, shoreline receding, dune system destroying, lowland flood, etc.) might affect coastal areas in the mid-long term, causing a great deal of damages.

To face all the uncertainties of the future and to be able to plan and manage coastal areas in a long-term way, the European Union has adopted two approaches: ICZM and Governance. On the one hand, the European Union encourage that coastal zone management should be based on ICZM principles through the use of: a broad and overall perspective which will take into account the interdependence and disparity of natural systems and human activities with an impact on coastal areas, a long-term perspective which will take into account the precautionary principle and the needs of present and future generations, and a perspective that involves all the parties and different administrations concerned in the management

process. ICZM also means the involvement of all relevant administrative bodies at the international, national, regional and local scales, which should improve their coordination and harmonize the multitude sectorial policies regarding coastal zones (EU ICZM Recommendation 2002/413/EC). On the other hand, Governance has become a key focus for enhancing integration across environmental management, particularly since the Aarhus Convention (Convention on Access to Information, Public Participation in Decision- Making and Access to Justice in Environmental Matters). European law makes principle of 'Good Governance'- characterised by openness, participation, accountability, effectiveness and coherence- a legal requirement in decision making. Appropriate Governance entails allowing adequate and timely participation in a transparent decision-making process by local population and stakeholders concerned with coastal zones
(PAC/RAC, 2007). Governance means that deliberation and cooperation between all stakeholders (institutional and non-institutional) should be a primary focus of a strategy development process for integrating coastal management. There is an increasing recognition of the need for a governance-based and pro-active approach to strategy development for coastal flood and erosion risk management (Mc Fadden et al., 2009).

Taking into account these approaches (ICZM and Governance) scenario making is considered a very valuable technique for coastal management. First, Scenarios provide a framework to deal with uncertain situations and complex environment (as coastal areas) and they offer a structured way of coping with the many uncertainties that lay ahead (Peterson et al, 2003). Different types of information (i.e. terrestrial and marine, quantitative and qualitative, or physical, socio-economic data) can be easily integrated in scenario making, even policies, and normative environment are often added to the scenarios. Thus a holistic and coherent approach to the coastal system can be taken when working with scenarios. And second, scenarios allow a participatory and open approach based on the involvement of all stakeholders. They can engage people form the beginning to the end of the process in an organised and structured manner, through innovative participatory techniques that promote deliberative and consensus-building exercises. Summing up, scenarios can combine both an integrated approach and Governance principles, therefore they show a great potential for coastal planning and management.

In order to develop a ICZM work method; the different types of integration must be taken into account.

- The integration of administrative grades (vertical integration) aims to harmonize national policies and regional planning with local implementation (international coordination can also be vital; which is the case of the Interreg programs).
- Intersectoral integration (horizontal integration) should allow for the taking into account of elements managed by various sectors, but the activities of which interact. (Example: tourism and fishing).

- Discipline integration, especially between scientists (natural or human sciences) and administrators (sciences and technologies with the aim of informing the administrator).
- Spatial and temporal integration should take into account the system of a coastal area considered as a whole (not limited to the coastline only) and should generate the largest scale of geographic analysis for the development of an information system.
- Integration of uses (cohabitation of activities) and the population (participatory democracy)

The ICZM process should be supported by investigation techniques and relevant analysis tools. These instruments will provide those who use ICZM with the information that they need, before helping them with decision-making.

- The analysis of public policies and governance modes for feedback on the smooth running of the ICZM process.
- The management of information to favour the development of a coastal information system; a practical tool to help with decision-making.
- The use of techniques for the evaluation, monitoring and follow- up of coastline trends.
- The use of regulatory (strong incentive plans to reduce pollution and retain resources) and economic (making users pay for the use of coastal resources) political instruments.

> ICZM indicator research

## Know the territory and the vulnerability

It is important to know the territory where the coastal enhancement and protection projects will be carried out in order to ensure that the works to be put in place correspond to the objectives of the commune and the risks incurred. This diagnostic must be carried out on the sedimentary cell with cohesion between the different cell communes for integrated coastal zone management.

First of all, the hazard that exists in the zone to be protected must be defined:
- Erosion
- Submersion
- Level of the hazard

Then the beach status must be described:
- Urban beach
- Natural beach

Finally, the stakes to be protected must be studied:
- Housing
- Shops
- Tourism
- Natural spaces

It is also important to determine the value of the beach; in fact, the works are chosen according to their cost and what they can bring. This diagnostic is used to determine the most vulnerable sectors, those which require priority action. In fact, by combining the data that relates to the scale of the natural hazards and the socio-economic objectives, we can characterize the sectors where the hazards are very significant and the objectives are very high; these zones are therefore considered as the priority sectors to be protected or enhanced.

## Take care about the future scenarios

There are many natural and human pressures that will affect coastal areas in the next decades, producing changes that must be considered by the coastal planners. In order to elaborate a consistent coastal plan it is very important to take a strategic and prospective approach, taking into account the territory characteristics and its vulnerability.

Without taking into account the future in a holistic and integral way, coastal management plans will be fragile and inefficient. The holistic vision consist of considering all the actors, issues and factors involved into the change processes that affects to the coastal area of intervention. The management scheme for a coastal area must be designed taking a long-term and strategic approach. Introducing future scenarios in coastal management ensure the consistency and robustness of the plans.
Future scenarios should be taken into account for the following phases of a coastal management plan:

- Establishing the core principles and strategic objectives and goals of the coastal management plan at both the short and longer term.
- Defining the temporal scale of the management plan.
- Defining when to review the plan and modify it if necessary.
- Identifying and coordinating relevant stakeholders.
- Drafting the spatial planning, i.e. which areas should be more protected, which areas are more or less exposed to risks, which areas are key points to economic development, etc.
- Assessing coastal risks, including the future hazards foresight in the scenarios and its possible effects.
- Evaluating and comparing possible measures to be considered in reducing coastal risks.
- Selecting the type of management mode for the coastal area.
- Choosing the type of coastal defence work.

To elaborate future scenarios the following aspects have to be considered:

### • Approach

Scenarios must be generated in an exploratory manner, so they attempt to assess specific impacts in different alternative futures. An explorative approach allows to ask “what if” questions and to explore the consequences of different development paths.

### • Temporal scale

The temporal horizons of the scenarios depend on the coastal management plan requirements. Based on the COASTANCE experience a minimum temporal scale of 50-100 years is recommended to take into account coastal hazards.

- Spatial scale

Coastal conditions -as physical characteristics, socioeconomic activities or institutional and legal context- vary widely from one region to another. Due to this reason, there are not future coastal scenarios applicable for all the Mediterranean; instead, specific scenarios should be developed for each region taking into account their specific characteristics.

- Dimensions

Future scenarios must consider both natural and anthropogenic aspects in order for them to be realistic. Bio-physical, socio-economic and political processes are integrated to create a complex but holistic approach.

- Participation

Stakeholders involvement is the key for the success of scenarios, as they are the ones that affect and are affected by coastal areas, thus, they influence the future development of the study area. Participation has to be promoted during all phases of the scenarios development from the very beginning.

- Climate Change and coastal hazards

Climate change and its possible effects -e.g. sea level rising, extreme storm events, shoreline recession, dune system destruction, low-land flooding, effects on coastal and marine biodiversity, etc. -should be a key aspect of the scenarios analysis.

On of the greatest advantage of using scenarios for coastal plans is their ability to compare competing viewpoints within a single framework, thus allowing coastal plans to be designed in a more robust manner. All short-term actions should be decided using a long-term and holistic vision. Scenarios are a powerful and innovative tool for coastal management in the current context of climate change and associated risks and they have an enormous potential if used during the planning process.

## Select the most appropriate management mode

Before the type of work to be built on the coastline is selected, the management mode to be applied must be defined. We can see 4 main management types which are associated with coastal defence works.
The choice of management mode must respect integrated management principles and be suitable to all the communes present within the same sedimentary cell. This choice is made taking account of the vulnerability of the coastline to natural risks, risks which are themselves determined according to the scale and position of the socio-economic objectives and the natural hazard estimate. The table below shows a classification of the different works according to the recommended management mode.

## Choose the type of work

As the previous table shows, the work chosen will depend on the results of the territorial diagnostic.
Certain works are more effective in responding to marine submersion and other for erosion risks. In addition, the choice of work takes account of a

site's urban development: a work will be adapted more to an urban beach or a natural beach.

Finally, when choosing the work, it is important to take account of the environmental impacts generated by its introduction. These impacts may be of no importance, serious but reversible and unfortunately often irreversible.

The table below summarizes all the criteria that enter the equation when choosing coastal defence works and is used to define the importance of the impact for each type of work that managers may encounter during the work.

It takes account of:

- The impact of the work on the coastline, i.e. if the work limits or stops erosion
- The impact of the work on the submersion risk, i.e. if the work enables the coastline to be protected from marine submersions
- The impact of the work on the swell, i.e. if the work enables the impact of swells to be limited along the shoreline and the coastline
- The impacts of the work on the environment during construction work
- The impacts of the work on the environment when operating
- The impacts of the work on the landscape
- The impacts of the work on bathing water quality
- The longevity of the work, i.e. whether it will need to be maintained regularly and if there is a risk of it being destroyed quickly
- The construction cost of the work in linear meters
- The type of beach for which the work is most adapted

## Select the construction site

The works may not be installed simply taking account of the needs of a project owner or a commune's elected representatives. In fact, the construction of works along the coastline and in natural areas is regulated by many town planning and nature protection laws.

- Town planning laws
- Nature protection laws
- Directives and conventions for nature protection

## Carry out an impact study

An impact study must be carried out for many projects. The diagram below is used to find out whether or not the project is submitted for an impact study. An impact study is not carried out at random. Its process is defined in article L 122-1 of the environmental code.

### 1- Analysis of the site's initial status and its environment:

- Definition of the study scope
- Study of the physical environment
- Study of the natural environment (inventories, ecological sensitivity maps, risks, regulatory standards, etc.)
- Description of the works
- Socio-economic context

### 2- Analysis of impacts on the environment:
- During the work phase
- After the work phase

### 3- Sanitary risk analysis

### 4- Proposed measures to remove or compensate for impacts

### 5- Analysis of the methods used

### 6- Communication of the assessment
Some very important criteria must be taken into account for the impact study to be as complete as possible. The table below lists these different criteria.

## Provide compensation measures
The project and the operation of the works generate negative impacts on the environment. In order to compensate for these impacts, measures must be put in place to balance the system.

The table below proposes a list of compensatory measures to be put in place according to the work installed.

Certain impacts caused by the works may not be compensated for; it is therefore important to select works whose impacts may be reduced.

## Carry out regular monitoring for the works and the coastline
Once the works are in operation they must be monitored regularly to check their condition, their effectiveness and that they do not harm the environment.
The following table presents the monitoring to be carried out for each work.
The coastline must always be monitored at the same period as the beach profiles vary naturally according to the seasons.

As some works require maintenance, monitoring will enable us to define if work needs to be repaired or consolidated. In particular, for beach sand top-up, it is vital to consider regular (every year or every 2 years) maintenance top-ups (lower sand volume).

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