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Coastal Storm Risk Assessment in Europe: Examples from 9 study sites

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ABSTRACT

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To assess coastal storm risks this paper compares existing hazards, associated risks, coastal management plans, and civil protection schemes from nine European countries. An evaluation made of specific study sites concludes that: (a) the definition of coastal hazard or risk varies between countries, regions and sites with no pan-European agreement; (b) existing risk definitions for northern Europe are based on probabilistic approaches and integrate threats to human occupation; this approach is not adopted in southern and eastern European countries; (c) half of the evaluated coastal management plans have a scientific basis with the remainder adopting qualitative or semi-quantitative approaches; (d) strategic approaches, used to define areas of potential occupation, coastal defences etc. are the most common; (e) operational approaches used for major event prediction and response are poorly developed. Therefore, there is a need to evaluate existing best practices in Europe in order to develop standardised coastal risk management for all EU member states.

ADDITIONAL INDEX WORDS: *Coastal Management, Civil Protection, Operational approach*

INTRODUCTION

Throughout history severe storms have affected European coastlines and each country has evaluated the impact of storms in different ways. However, at present, there is no pan-European consensus regarding hazard levels, risks, management plans and civil protection schemes. Following identification and evaluation of existing coastal management plans and civil protection schemes, this paper appraises how coastal risk assessment has been undertaken at nine different European sites. This work is a part of the European Union funded MICORE - Morphological Impacts and COastal Risks induced by Extreme storm events – project, whose main objective is to develop and demonstrate on-line tools for reliable predictions of the morphological impact of marine storm events in support of civil protection mitigation strategies.

The concepts and expressions used in this study are based on the TC32 Glossary[1] of existing disaster terminology. For the purpose of this paper *vulnerability* is defined as a function of the hazard represented by the forcing conditions (winds, waves and tidal levels) that favour damage, and the predisposition of people and properties to be affected by marine storms. *Hazard* is the probability of a given danger (threat) to occur within a given period. Once a hazard becomes effective, it can create an emergency situation. An *extreme event* is defined as an event with a very low annual exceedance probability. The *consequence* of an extreme event, in relation to risk analysis, is the outcome or result of a hazard being realised. *Probability* is an estimate of the likelihood of the occurrence of an event/hazard. *Risk* is the measure of the probability and severity of an adverse effect to life, health, property, or the environment. For the purposes of this paper it is defined as Risk = Probability x Consequence (Vulnerability).

Risk assessment is the process of making a decision or recommendation on whether existing risks are tolerable and present risk control measures adequate, and if not, whether alternative risk control measures are justified.

STUDY AREAS

The European coastline is formed by Coastal Regions with widely different morphodynamic behaviour, coastal hazards, socio-economic and tourism-related features. The six Coastal Regions identified are Mediterranean, Baltic, North Sea, Atlantic, Black Sea and Outermost regions. With the exception of the Outermost region, this paper considers the following studies sites in all these regions (Figure 1):

1) Belgium (Mariakerke Beach)

The dissipative Mariakerke beach is characterised by a low gradient and a surf zone with numerous spilling breaker lines. Storm events can cause strong erosion and impacts (e.g. the storm of 1976). The harbour of Oostende intercepts the longshore sediment flux and locally disturbs the morphological equilibrium. Due to the socio-economic, cultural, ecological and recreational value, this area challenges coastal managers.

[1] http://www.engmath.dal.ca/tc32/OsakaReport2005.html

Figure 1. Distribution of study sites in Europe.

2) Bulgaria (Kamchia-Shkorpilovtsi Beach)

The Kamchia-Shkorpilovtsi beach is the longest (13 km) sandy beach in Bulgaria, with well-developed dunes and two rivers, one of which (Kamchia) being the biggest Bulgarian river flowing to the sea. The site is exposed to storm waves in the Black Sea from the north, northeast and east. Here, the main issue is a high vulnerability of dunes and river mouths to storms, which can affect ecological areas and recreational facilities.

3) France (Lido of Sète to Marseillan Beach)

The narrow Lido of Sète sand spit, in the Languedoc-Roussillon Region, is 13 km long and separates the lagoon of Thau from the Mediterranean. It is presently very vulnerable to coastal erosion and sea level rise. As this area includes housing, vine growing and tourism infrastructures, this poses serious economical, social and environmental risks. The coastal road, as well as the national railways, are located on the dune system and are particularly vulnerable during storms. The main issues are related to overwash processes, shoreline retreat and dune erosion.

4) Italy (Lido di Dante-Lido di Classe, Ravenna)

The area encompasses an 8 km sandy beach along the Emilia-Romagna coastline, facing the Adriatic Sea. Here the main issues are related to dune erosion, overwash processes and subsidence. The area is partly located in a natural park and partly exploited for tourism and oil extraction activities. There are three river mouths: Fiumi Uniti (northern boundary); F. Bevano (central part); F. Savio (southern limit). Part of the site is protected by breakwaters and groynes and subject to beach replenishment schemes. The recreational value of the area is very high and supports many economic activities along the coast.

5) Netherlands (Egmond Beach)

Egmond is a 5 km long beach located in the Northern part of the Dutch coast. It comprises dune areas, sandy beaches and multiple-barred nearshore zones. On average, the beaches are approximately 60 m wide with a 1:40 slope. Since the implementation of the Dynamic Preservation policy (early 90's) this coastal stretch is among the most frequently nourished areas in the Netherlands.

6) Poland (Dziwnów Spit)

The sandy Dziwnów Spit is c. 0.4 km wide and 11 km long with low dunes and separates the Baltic Pomeranian Bay and the Kamienski Lagoon. The coastline is very sensitive to flooding by storm surges. Dziwnów town is located in the narrowest part of the spit at the eastern side of the river mouth and is protected by groynes, a sea wall and nourishments. The Kamienski Lagoon coastline is very sensitive to flooding by storm surges. The whole area is an important tourist resort during summer.

7) Portugal (Praia de Faro)

Praia de Faro is an 8 km long sandy beach located in the Ria Formosa barrier-island system, Southern Algarve. Here the main issues are related to dune erosion, overwash and island breaching. The Ria Formosa is an extremely dynamic system, vulnerable to events leading to erosion. Several economic activities take place at the site, of local and regional importance, such as aquaculture, salt extraction, fishing and tourism.

8) Spain (Urban beaches of Cadiz Bay)

The field site is 10 km long and comprises both highly urbanized areas and nearby natural zones. The urban beach (La Victoria), located in Cadiz city, is backed by a promenade and it was artificially nourished twice since 1992. The natural beach (Sancti Petri sandspit) is backed by dune ridges and salt marshes. Here overwash processes are quite frequent.

9) United Kingdom (The Eastern Irish Sea)

The Eastern Irish Sea coastline between the Dee and Ribble estuaries hosts a wide range of industrial, commercial and residential buildings as well as coastal types (sand dunes, tidal flats, mud flats, salt marsh and hard engineering structures). The coastal area is vulnerable to coastal flooding during extreme storm events and its fragile ecosystems are sensitive to storm impacts. The study site is at the heart of a coastal observing system making it exceptionally well-monitored and modelled.

MANAGEMENT PLANS

Belgium (Mariakerke Beach)

Coastal protection in Belgium is a regional responsibility. The minimum safety level for the coastal protection defined by the Flemish government is the 1:1000 year event. However, this safety standard is not statutory. The safety of all coastal defences is checked every 5 years and an annual monitoring of the entire coastline allows updating of safety levels. Beach nourishment is also carried out annually. At present a large number of coastal communities do not achieve the defined safety standard and a 1:100 year safety level is maintained as a minimum along the entire coastline.

A new management plan is currently under development (Integrated Master Plan for Flanders Future Coastal Safety). This plan will detail the priorities and the needs for coastal protection along the coastline up to 2050 in order to minimise the risk of flooding. Completion of the study is expected by 2010.

Bulgaria (Kamchia-Shkorpilovtsi Beach)

At present there is no specific Management Plan for the Bulgarian coastal areas. The existing urban plans for coastal regions do not include coastal storm risk assessment.

France (Lido of Sète to Marseillan Beach)

In France, the legislation is driven by the "Littoral" Act of 3rd January 1986. This law aimed to structure coastal management and prevent abusive coastal urbanization. The prevention of construction in the 100 m coastal strip was a first step to reduce vulnerability. However, this principle does not apply to existing urban areas. The control of urbanisation of the coastal zone is undertaken within the urbanism plans (SCOT – Scheme of Territorial Coherence, and PLU – Local Urbanism Plan). From 1995 (Barnier law), where a natural hazard exists, Risk Prevention Plans (PPR) have to be set up and to be taken into account in the

urbanism plans (SCOT and PLU). Since 2000 the marine flooding risk is taken into account in continental flood PPRs. Information regarding coastal risk and measures taken by the authorities to prevent these risks must be provided to the populations.

In the Languedoc-Roussillon region, the MIAL (Mission Interministérielle d'Aménagement du Littoral) initiates at the end of the 90's a reflection on the regional coastal erosion and provides strategic guidelines for the management of the coastline. Coastal management priorities and procedures were defined after an erosion hazard evaluation and validated at local to regional scale. Solutions to prevent erosion are now undertaken following the logic of ICZM. The strategic retreat, restoration of dynamic equilibrium and preservation of natural behaviour are encouraged.

Italy (Lido di Dante-Lido di Classe, Ravenna)

The Regional Council (Emilia-Romagna) adopted the ICZM Guidelines, by Act n. 645 of 20th January 2005, following the Regional Government's proposal n. 2406 of 29th November 2004. The ICZM Guidelines encourage an integrated and cross-sectoral approach, define principles for best-practice in all coastal activities and positively address the factors affecting this area, both at the landward and seaward side. The coastal defence strategy is based on the improvement of the monitoring network and system knowledge, and on the extensive use of nourishment rather than hard coastal defence. The Regional Law 20/2000 has included European and National directives on sustainable development concerning planning at a Provincial Level in the context of Climate Change. However, no formal regulation of planning that accounts for coastline position is implemented.

Netherlands (Egmond Beach)

In the Netherlands the regulations related to flood risk are generally referred to as the 'safety chain'. The safety chain distinguishes a number of separate phases, viz. pro-action and prevention, preparation, response and mitigation, and aftercare.

Pro-action and prevention deal with all measures to remove causes of risks. Main categories to be distinguished are (1) spatial planning measures regulating the potential worth of losses and (2) measures to reduce the hazards regulating the probability that a particular danger (threat) occurs within a given period. In the Netherlands nourishment is the preferred method for storm surge hazard reduction.

Preparation, response and mitigation concern the measures related to the actual preparation, response and support during disasters. All waterboards (regional water management authorities) have contingency plans to protect the flood defences. Although the areas on or in front of the coastal defences are the first to be hit in cases of a severe storm, there is no specific attention in these contingency plans to those areas. It is unclear whether the public is fully aware of the nature and magnitude of the risks and their possible personal consequences.

The aftercare aims for the return to the normal situation, after a disaster. The Calamities Compensation Act serves as a safety net for financial damages. However, damage caused by coastal erosion or flooding in coastal towns is not explicitly mentioned under the conditions for financial compensation. Nevertheless, it is expected that in case of a coastal disaster with a national impact the Act will be enforced after a Royal Decree.

Poland (Dziwnow Spit)

The existing Management Plan has been prepared on the base of Parliament's Act n. 621 from 28th March 2003 about the "Sea coast protection program 2004-2023". This program is a part of the "Strategy of coastal protection" prepared by a consortium coordinated by the Maritime Institute in Gdansk. The Strategy takes into consideration the current state of knowledge and understanding of the dynamics of the Polish coast and also the development of coastal zones as well as the environmental values. As a consequence of its entry into force, long-term plans for the coastal protection should be created. The Strategy places special emphasis on areas threatened by sea floods and intensive coastal erosion as well as on areas of high level of investments. It also takes into consideration predictions of climate change. All activities defined in the Strategy are agreeable with the imperative rule of integrated development.

Coastal safety is defined as the resilience to storm surges with a defined probability of occurrence and uses five security levels from 20 to 500 years return period.

Portugal (Praia de Faro)

As there is no consistent approach to management of coastal hazards for the Portuguese coastline, each management plan has different methods. The Portuguese legislative framework valid for the Ria Formosa barrier system includes the Algarve Regional Land-Use Management Plan (PROTAL), the Vilamoura-Vila Real Sto António Coastal Management Plan (POOC), and the Ria Formosa Natural Park Land-Use Management Plan (POPNRF).

The PROTAL defines set-back lines for human development, building regulations and land-uses. The plan proposes soft-engineering techniques whenever monitoring results recommend intervention. Specific coastal hazards are sporadically mentioned in the document. Coastal erosion is the only coastal hazard represented in the Natural Hazard Map used by PROTAL. POOC defines rules for spatial planning of land-use along the coast. The plan recognises the importance of maintaining the natural morphology and dynamics of beaches and dunes. POOC's set-back lines are in agreement with PROTAL's but includes other specific protection lines related to inlet migration, overwash and dunes preservation. It only considers potential hazards and not potential damages, and thus does not define risk. However, it identifies areas potentially subjected to risk. POPNRF includes an evaluation of coastal hazards, mainly based on the analysis of coastal erosion.

Spain (Urban beaches of Cadiz Bay)

The urban beaches are subject to municipality's plans and the natural beaches belong to the Bay of Cadiz Natural Park (BCNP). Therefore, management plans can be divided into two main types:

a) Plans for urban areas: General Urban Development Plan for San Fernando (1992); General Urban Development Plan for Cadiz (1995); Sub-regional Plan for Spatial Planning in the Bay of Cadiz (2004); New General Urban Development Plan for San Fernando, (2006, under revision); New General Urban Development Plan for Cadiz (2007, under revision).

b) Plans for protected areas: Plan for Natural Resources of the BCNP (2004); Plan for the Use and Management of the BCNP (2004); Plan for Sustainable Development of the BCNP (2006).

Most of these management plans make little references to coastal risks associated with marine processes and only briefly consider beach erosion. Where coastal risks are included, they are only used to assess the present situation. None of the plans includes storm risk evaluation procedures or related management approaches.

United Kingdom (The Dee Estuary)

In the UK, there are two types of management plans relevant to coastal hazards and risk management: the Shoreline Management Plans (SMPs) and the Catchment Flood Management Plans

(CFMPs). The SMPs are devised by local authorities in charge of specific coastal segments (policy units) taking into account the legislative framework and guidance provided by DEFRA (Department for the Environmental, Food and Rural Affairs). A new round of SMPs is expected to be open for consultation in 2009. The plans will cover three different time periods 0-20 years, 20-50 years and 50-100 years. For a given time-period and unit SMPs will recommend one of the following options: (a) hold the line (maintain the existing defence line); (b) advance the line (build new defences seaward of the existing defence line); (c) managed realignment (breaching or removing defences to allow controlled flood to promote development of salt marshes); and (d) no active intervention (defences are not maintained or implemented). The CFMPs are produced by the Environment Agency (EA) with the aim of reducing flood risk (from rivers, groundwater, sea and sewers) and provide mechanisms for a sustainable long-term flood risk management. New CFMPs are being published at present. Operating authorities responsible for coastal and flood defence (i.e. local councils and the EA) have permissive powers, which means that they are not generally obliged to undertake risk management measures. Therefore, the level of risk management provided varies considerably from one administrative district to another.

In the study area, there are two SMPs into force, the Ribble Estuary SMP and the Liverpool Bay SMP. Within SMPs, specific Coastal Process Units (CPU) are defined based on similarities of coastal processes, land use and flooding/erosion risk. The study area presents three CPUs within the Liverpool Bay SMP: CPU5 Dee Estuary (outer), CPU6 Dee Estuary (inner), CPU7 North Wirral and Sefton (Seaforth Dock to Formby Point); and four CPUs within the Ribble Estuary SMP: CPU5 (Warton/Crossens to River Douglas), CPU6 (Crossens to Southport), CPU7 (Southport to Ainsdale) and CPU8 (Ainsdale to Formby). Within the study area, there are also three CFMPs in action: The Mersey Estuary, the Alt Crossens and the Ribble, all considering relevant points to coastal flooding and risk management.

RISK EVALUATION APPROACHES

Two different risk evaluation approaches are considered: *Strategic*, for planning on a decadal to centennial basis, integrating a time-scale approach that can be used as a probability assessment (e.g. vulnerability indexes, set-back lines, hazard and risk maps); *Operational*, based on real time observations/predictions coupled with models and used for emergency plans (e.g. real time models associated to warning systems).

Strategic Approaches

There are no implemented official strategic approaches for the Bulgarian, Polish, Portuguese and Spanish sites. Strategic approaches for these areas are currently under development in the MICORE project.

For Belgium, the Flanders Masterplan includes flooding maps and estimates overtopping along the coast associated to given return periods. Coastal erosion is not directly considered.

At the French site the methodologies to assess hazard and vulnerability were developed by private companies, within the scope of the "Strategic Orientations" defined by MIAL. Hazard maps have been made based on the historical shoreline retreat and extrapolating the mean rate for the next decades. There is however no specific PPR for coastal hazards and marine flooding.

For the Italian study area, a coastal risk assessment based on probabilistic approaches is currently being developed for the regional authorities by the University of Ferrara and the Geological Survey of the Emilia-Romagna Region.

In the Netherlands well-defined procedures, for the purpose of pro-action and prevention, have been established and implemented in the framework of the Safety Assessment Regulation. This procedure is governed by the Flood Defences Act and the assessment is executed every five years.

The UK Environment Agency (EA) produced Flood Zone maps using the flood model JFLOW. This has been used to produce the 1% (1 in 100 year) and 0.1% (1 in 1000 year) flood outlines for the UK that include fluvial and marine components. Therefore, flood risk is associated with the return period of flood events, which may be a combined probability of certain storm surge levels coinciding with high tides, high waves and heavy rain.

Operational Approaches

For the study areas of Belgium, Bulgaria, France, Italy, Portugal and Spain there are no implemented operational approaches. For these sites the only real time warnings are alerts for navigational purposes issued by the meteorological agencies. These alerts are not connected with any other kind of warning plan or intervention. In Belgium a warning system exists based on water level records but not on forecasts. When the water level exceeds 5.6 m above the mean low level of spring tides an official alert is released. When the water level exceeds 5.9 m it is settled an official storm tide alarm.

The exceptions are Poland, Netherlands and UK were to some extend there are already some operational approaches linked to warning systems. In Poland the warnings are based on the results of meteorological and hydrodynamic models that predict wind velocity and sea level elevation. Action is taken only if conditions above a defined threshold are observed. Although in the Netherlands an operational surge forecast model is used, it presently excludes waves, morphology or coastal erosion and flooding. It is used as a warning tool for authorities to guide the implementation of various levels of "levee watch" or "levee patrol", and to inform decisions regarding the closure of moveable barriers in estuaries. In the UK tide-surge models are used to forecast storm surges for the EA. The models are run twice a day in real-time at the Met Office. This service provides the crucial warnings needed to protect coastal communities from the threat of flooding, as well as aiding in operational decisions such as when it will be necessary to close the Thames Barrier. The waves are forecast by the UK waters wave model, which runs daily at each 6 hours, giving a 48-hour forecast. Linked with forecasting surge elevations, tides and waves are the range of methods available for predicting peak and mean wave overtopping volumes and discharges at coastal structures. The operational approach does not consider at present coastal erosion or associated risks.

CIVIL PROTECTION SCHEMES

All analysed countries and study sites have well defined and established civil protection schemes, implemented at national, regional and local levels. These schemes are sometimes rather complex, and the existing cascading system can delay and hinder information exchange to relevant parties, including the public. With respect to coastal and storm hazards there are, however, only few countries that have specific plans. Most of the study sites do not consider a specific civil protection scheme for storm hazards or only considered one of the potential hazards (e.g. sea floods).

At Bulgaria, France, Portugal and Spain sites there are no specific civil protection schemes for storm risk consequences. In some of these countries warnings exist for wave heights although mainly aimed at navigational safety. In Spain, at the regional (Andalusia) level, there is only a recommendation stating "in

coastal areas, keep away from beaches and lowlands that can be affected by high surges and waves generated by strong winds."

For the Belgium coast there is no emergency plan for flooding or other coastal hazards, with the exception of the Oostend town (70,000 inhabitants) where a specific emergency plan exists. The current civil protection scheme integrates a storm alarm and the closing of the storm defences.

In Italy, coastal erosion and sea storms are considered as a special case of the hydro-geological risk by the Protezione Civile Nazionale, while for the Emilia-Romagna region coastal hazards are included into the procedures for the "other types of hazards" (i.e. winds, storm waves, fog, snow avalanches). Warnings are issued if the sea state model shows the possibility of occurrence of a wave height equal or greater than 2 m and/or the meteorological model forecasts a wind intensity equal or greater than 22 knots. The probability of a high sea level due to storm surges is also forecasted. The Civil Protection sends an alert to local authorities and operational structures of the "alerted area", summarizing the information reported by the meteorological warning and indicating the possible effects of the storm, the actions that should be taken by the authorities and the recommendations for people.

For the Egmond Beach and surrounding coast civil protection schemes with particular attention to coastal erosion and localised flooding have not been established. The existing plan is very brief and focuses entirely on in-land water-related calamities, i.e. flooding of polders. However, in other coastal regions of the Netherlands (e.g. Rijnland) the calamity control plan integrates a coastal hazards section. This section differentiates five stages of emergency, triggered by the prediction of the water level (forewarning, incident, impending calamity, impending calamity with impact, calamity). This plan do not uses real time information and is not based on state of the art morphodynamic models.

In Poland, Civil Protection Schemes regarding storm impacts exist in two cooperating institutions: the local/regional government and the Maritime Office. Based on observations they incorporate a level of Storm Readiness (for wind strength exceeding 8 Bft or water level exceeding 0.60 m above sea level) and a level of Storm Alert (for wind strength exceeding 9 Bft or water level exceeding 0.80 m above sea level). Actions against storm impacts are taken by the Maritime Office.

DEFRA has policy responsibility for flood and coastal erosion risk management in England. The EA has the role of overall supervision over all flood defences, is in charge of providing flood warnings and is responsible for flood defence measures covering main rivers and the sea. Local authorities (i.e. local councils) are responsible for coastal protection, flood defence measures covering ordinary watercourses and the sea, and provision of emergency aid during floods. Internal Drainage Boards (IDBs) are in charge of flood defences and management covering ordinary water courses within their districts. There is, however, no IDB at the study area. Some local authorities have implemented Major Incident Plans which include operational emergency response for flooding events.

CONCLUSIONS

From an evaluation of risk, existing coastal management plans and the civil protection schemes from each study area, the following general conclusions can be drawn. (1) The definition of coastal hazards and coastal risks for European countries is country specific and in some cases even regional or site specific. (2) Existing risk definitions in northern European countries are based on a probabilistic approach and integrate the threat to human occupation. In southern Europe, risk definitions are not normally based on a probabilistic approach and/or do not integrates human occupation. (3) For eastern European countries probabilistic mapping is still at an early stage and only limited information is available at a wide scale. (4) About half of the European coastal management plans lack a solid scientific basis. The remainder are based only on available qualitative or semi-quantitative information and take the form of hazard maps, protection areas, and other forms of semi-qualitative information. (5) A lack of robust data sets to inform policy can result in a subjective identification of vulnerability parameters and the development of inappropriate coastal management plans. (6) Strategic management plans targeted for land use management, potential areas for occupation or conservation and for coastal defence are the most advanced at present. (7) With the exception of coastal flood forecasts for Poland, the Netherlands and the UK, operational approaches to coastal risks do not exist in the rest of the study sites. (8) There is a general perception that coastal floods can pose serious threats to coastal communities. However, the response protocols are usually poorly developed and mainly targeted at evacuation procedures, rather than mitigation. A notable exception is the case of countries bordering the North Sea where past experiences of severe coastal flooding resulted in a high level of preparedness. (9) Italy, the Netherlands, Poland and the UK have specific civil protection schemes to face coastal storm risks. These do not exist in Belgium (to be implemented by 2010), Bulgaria, France, Portugal and Spain. (10) In the case of northern European countries, where coastal flooding in the past has resulted in the loss of human life, the problem is well-known to coastal communities, to governments and the media. In southern and Eastern European countries the main concern is the damage to properties or impact on local economies.

With these points in mind the following improvements at a European level are suggested, which partially coincide with the aims of the MICORE project. (1) Establish a probabilistic-based approach for risk definition for all countries. (2) Establish the basis to implement operational, quasi real-time, coastal risk assessment methods for all countries. (3) Evaluate and compare different risk assessment methods. (4) Fully exploit existing datasets and acquire new field data for the improvement and development of prognostic models. (5) Fully integrate models with future management plans.

At present there is no common European consensus, policy or approach towards coastal risk assessment. To be effective, this needs to be addressed at EU level, taking best practice from a range of European countries, and developing coastal management strategies that address the individual threats along the diverse shorelines of Europe.

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