Indicator	
27	Natural, human and economic assets at risk.
Measurement	
27.2	Area of protected sites within an ‘at risk’ zone.

What should the measurement tell us?

As a result of climate change, some areas on the coast may disappear due to coastal erosion, may become permanently inundated by the rise in sea level or temporally flooded due to an increasing incidence of terrestrial and/or marine storms. The first two threats are of importance because they potentially lead to a loss of a rich coastal ecosystem, while the latter (flooding by rivers) can be considered as an event that has shaped the protected habitat.

One method to assess potential damage on natural assets is by measuring the area of protected sites within an ‘at risk’ zone. The protected sites are the sites with the highest natural values for the described coverage. The proposed measurement does not directly indicate the natural value at risk, however, there is a good correlation with natural value and, in general, with biodiversity affected.

There are areas protected by European statutory designations (Natura 2000), national and regional statutory designations. The marine protected areas are excluded from this measurement because the analysed risk does not apply to the marine ecosystem.

There are other threats to be considered when looking at natural assets at risk in the coastal zone. One aspect that is not incorporated in this measurement is the threat of modification of habitats as a result of climate change, such as rise in temperature or related water quality parameters.

Parameters	
(i)	Natural coastal protected area ‘at risk’ zone by RSLR, coastal erosion, river flooding, marine storms flooding or any of these.
(ii)	Percentage of coastal natural protected area ‘at risk’ zone by RSLR, coastal erosion river flooding, marine storms flooding or any of these on the wider reference area.

Coverage	
Spatial	**Temporal**
Coastal municipalities strip[1].	Currently

Data sources

The incidence of the climate change on the coastal zones has been evaluated by the Intergovernmental Panel on Climate Change (IPCC) http://www.ipcc.ch/. Chapter 6 of 'Climate Change 2001: Impacts, Adaptation and Vulnerability' focuses on Coastal Zones and Marine Ecosystems. Moreover, the particularity of each continent is specified (Chapter 13 for Europe).

This reference provides criteria for the establishment of the area at risk but, in general, they are not specific enough to be directly applied for delimiting the area at risk.

RSLR: The IPCC has established the evolution of the sea level throughout the century in different scenarios (parts 3.6.2-3.6.6). It presents a common estimation for all seas but the relative rise must incorporate any local component due to vertical displacement of land such as subsidence.

Inundation by river floods: Many countries have produced assessments of the areas at risk of river flooding linked to a defined return period (period with a high probability of registering the incidence that causes the risk one time). On 18 January 2006 the Commission adopted its proposal for a Directive of the European Parliament and of the Council on the assessment and management of floods (COM(2006)15 final of 18.1.2006). The directive will impose the implementation of flood risk management plans in which the first step is to take into account the areas affected. Areas likely to be inundated by river floods will be estimated from existing studies from regional/national agencies. In order to follow the proposal of the Directives, it is recommended to use the delineation of area to be inundated by the flood of 100 year return period.

Coastal erosion: In a few countries, there is an estimation of the area affected by coastal erosion. A typical example is *National Appraisal of Assets at Risk from Flooding and Coastal Erosion* (http://www.defra.gov.uk/environ/fcd/policy/NAAR1101.pdf) produced in 2001. That report computes 'annual average damage' differentially caused by coastal erosion, sea and tidal flooding and fluvial flooding under different scenarios such as, do nothing, improve defences to current standards and improve to enhanced standards. Information is presented for a NUTS 2 geography but is compiled from local data which it should be possible to obtain. Areas subjected to erosion as well as the extension of the erosion (erosion rates) will be taken from existing studies by regional/national agencies.

Inundation by coastal storms: As in the case of river floods, the area 'at risk' is related to a specified return period. The water level must include the contribution of storm surges and wave run-up. For this calculation, long time series of wave and water level data are required. When they are not available, they can be substituted by simulated and/or hindcasted data.

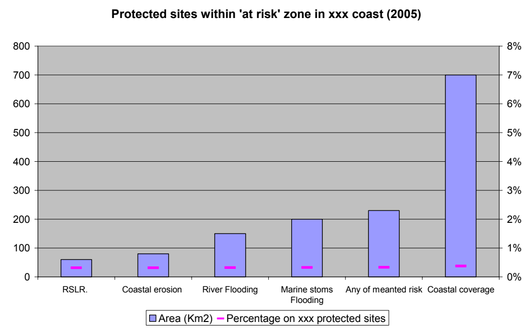
Once the vertical data (projected inundation levels) have been obtained, it will be necessary to define a digital terrain model (DTM) of the area of study to estimate the extension of the affected area.

Finally, the data for protected areas NATURA2000 is available from the European Environment Agency. The data on national and regional systems of protected areas is available in national and regional environment agencies or ministries.

Methodology		
	Steps	**Products**
1	Add the cartography of the areas protected (by law or by other effective means) for environment values and landscape: - European statutory designations: Natura 2000 - National and regional statutory designations: national parks, natural parks, areas of natural interest, or any statutory designation existing in the reference region. - Areas housing protected habitats: only if reliable cartography is available for those habitats - Areas protected by regional/national spatial planning: only if they provide firm and immovable protection against development (ex. local councils cannot change land qualification)	Cartography and areas of European, national and regional protected areas in the wider reference region.
2	Clip the integrated cartography of protected areas with the coastal coverage (in this case coastal municipalities) and obtain statistics on the protected areas in this coverage	Cartography and areas of coastal European, national and regional protected areas.
3	Using a digital terrain model (DTM), delineate the area with direct connection to the sea located below the elevation of relative sea level rise (RSLR) in year 2100, which is 0.5m [2] modified by local level of vertical land displacement, if it is known.	Cartography (GIS layer preferably) of the area below RSRL in 2100 at best guess.
4	Delineate the area likely to be inundated by a river flood of 100 year return period (or take it from already existing analysis).	Cartography (GIS layer preferably) of the area affected by a river flood of 100 year return period.
5	Using a DTM, delineate the area with direct connection to the sea located below the wave run-up[3] of 100 year return period. The tide elevation might be combined with the run-up for a more exact value of sporadic sea water elevation on land.	Cartography (GIS layer preferably) of the area below sea water level associated to a coastal flood of 100 year return period.
6	Obtain values of coastal erosion rates (m/year). Project these rates to estimate the retreat in 2100 (the process is simplified by assuming that erosion rates will be constant during such periods). In protected areas (e.g. urban zones) where coastal retreat is limited, this erosion will not be considered for the analysis.	Cartography (GIS layer preferably) of the area at coastal erosion risk for a return period of 100 years.
7	Add the risk areas associated to each process (four): coastal flooding, river flooding, coastal	Cartography (GIS layer preferably) of area to be affected by any risk source.

	erosion and RSLR to obtain the area affected by any risk.	
8	Overlap the cartography of coastal European, national and regional protected areas with the different affected areas evaluated in points 3, 4, 5, 6 and 7. Obtain statistics of the extension of protected areas 'at risk' by each factor and any of them.	Extension of Coastal European, national and regional protected areas at risk by each process and any of them.
9	Divide the coastal protected area at risk (it includes the area of any risk) and the protected area in all the coastal zone by the protected area of the wider reference area and multiply by 100%	Percentage of coastal protected area 'at risk' on the wider reference area.

Presentation of the data

Map 1	Map representing the protected areas by typology in coastal municipalities and the 4 different areas at risk by means of complementary plot.	
Graph 1	Bar chart with double axes: 1 axis: Columns showing the extension of protected areas at risk zone: RSLR, coastal erosion, river flooding, marine storm flooding and the union of them and the protected area in the coastal zone (5 columns). 2 axis: Points of the percentage of the 5 referred categories of protected areas on the protected areas in the wider reference coverage.	

Adding value to the data

Deleted:

Different risk areas might be considered according to different previsions (more probable or less probable). Moreover, a risk zone might be defined on account of future protection structures.

Results can be calculated using coastal buffers of 1km or 10km as coastal coverage.

Aggregation and disaggregation

Steeps can be implemented and results can be obtained separately by each typology of protection.

At risk appraisals can be undertaken on any spatial scale.

Notes

[1] This administrative coastal coverage has been taken for maintaining the same coverage as the previous measurement of this indicator: population inside the area 'at risk'. For that measurement some steeps of calculation needs use the inhabitant in each coastal municipality

[2] The Intergovernmental Panel on Climate Change (IPCC) forecasts that by 2100 the sea level will have risen by 20-90 cm around the world. The best guess (more probable situation) is 38 cm. The option that has been taken for this methodology is the level of 50cm instead 38cm, because we do not use a level of precision of cm. In addition to absolute sea level modification, there is a vertical displacement of land, with local values.

[3] The wave run-up is the temporary elevation of sea level rise when the wave reaches the land and progresses on it. It is the sum of setup, the time-averaged water-level elevation at the shoreline due to waves (excluding tides and surge), and swash, the time-varying, vertical fluctuations about the temporal mean.

The most correct parameterisation of the run-up is exposed in "Predicting the Longshore-Variable Coastal Response to Hurricanes" - Stockdon, H.F., Holman, R.A., Howd, P.A. & Sallenger Jr, A.H. 2006. Empirical parameterisation of setup, swash, and run-up. *Coastal Engineering*, 53, 573–588.

The elevation of run-up maxima has been shown to be dependent on deep-water wave height (H_0), wave period (T_0) and the foreshore beach slope (β_f). The elevation of the 2% exceedence level for run-up, R_2, can be calculated using the empirical parameterisation:

$$R_2 = 1.1\left(0.35\beta_f(H_0L_0)^{1/2} + \frac{[H_0L_0(0.563\beta_f^{\,2}+0.004)]^{1/2}}{2}\right)$$

where L_0 is the deep-water wavelength, defined as $gT_0^2/2\pi$ [Stockdon et al., 2006].

(This equation is extracted from *of the* Abstract of dissertation of Hilary F. Stockdon for the degree of Doctor of Philosophy in Oceanography presented on April 5, 2006. More information in part *4.4.3.3. Estimation of Wave Run-up and Setup,* p.83 http://ir.library.oregonstate.edu/dspace/bitstream/1957/1930/1/stockdonPhdThesis2006.pdf,)

For calculating the run-up for a return period of 100 years, the values of two required features of waves must be used: deep-water wave height (H_0), wave period (T_0) related to such return period. These values must therefore be previously estimated from an existing extreme wave climate in each tide gauge available in the coastal region of the coverage. The extreme wave climate is an analysis that provides the probabilistic Weibul function, which relates return periods with wave heights.

In most cases it will be adequate to calculate the equation with two slopes characteristics of the beaches of the select area: one for reflective -steep and coarse sediment- and one for dissipative -mild and fine sediment.

It would be necessary to consider the contribution of the meteorological tide to the run-up. To do this, we shall need a simultaneous water level (ξ) time series of a joint storm-surge wave distribution to associate a probability with each pair of H and ξ, but this is complicated. The value of H used in Stockdon's run-up equation might be the sum of both components: height of wave and tide elevation The procedure to include this component to the previous one will be simply adding the value associated to the selected probability to the estimated run-up.