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Beach Multi-Risk Assessment in the Costa Brava (Spain)

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ABSTRACT

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Beaches are complex social-ecological systems that provide several goods and services improving human well being. Both an excessive development of the Tourism industry and an increase of coastal hazards have been identified as important factors inducing coastal degradation and affecting the natural supply of these services. Nevertheless, traditional beach management has been concentrated on geomorphic hazards and beaches recreational uses, overlooking their broader functions. Risk analysis is recognized as a tool to assist decision making, helping managers to prioritize issues and focus efforts in the activities with the greatest potential impact. However, as beach management, traditional risk management overlooks beach environmental values, focusing on damages to assets and not considering the total risk in management. In response to the need to incorporate integrated and proactive tools which assist coastal managers, we apply a beach multi-risk assessment in S´Abanell beach (Spanish Mediterranean), in order to prioritize the most risky hazards and the most affected ecosystem services, helping the manager to decide where to allocate resources to cope with hazards affecting beach's functionality. Seven coastal hazards and five ecosystem services have been characterized. River floods and Coastal storms were the riskiest hazards, while Recreation & Aesthetic was the most affected ecosystem service in S´Abanell beach. Risk valuation has been obtained based on hazards intensities and the ecosystem services economic valuation. The inclusion of these non-market values in the risk assessment improves risk analysis, and should help managers to make more accurate decisions in an integrated beach management process.

ADDITIONAL INDEX WORDS: *beach, multi-risk, coastal hazards, ecosystem services, ICZM.*

INTRODUCTION

Beach social-ecological systems are usually viewed as natural places supporting hedonic socio-cultural activities (*i.e.* sun and sand) when in fact these ecosystems should be seen as complex multi-dimensional and multi-functional systems (James, 2000; Ariza *et al*, 2008a). In terms of environmental functions, beaches improve human well being to a significant extent, providing several goods and services (*e.g.* disturbance regulation, bioremediation of waste, cultural heritage and identity, nutrient cycling, habitat, gas and climate regulation, leisure and recreation), which could be grouped into three main functions:

- the natural function, where beaches provide natural sceneries and ecological reservoirs, including physical supports for ecosystems,
- the recreational function, which considers the beaches as an area of leisure and free time for the users,
- the protection function, which concerns the beaches capacity to absorb the wave's energy during the impact of coastal storms, protecting the hinterland's infrastructures during and after the storm (Ariza *et al*, 2008b).

As transitional areas, beaches suffer intense physical, ecological and social interactions, being exposed to both aquatic and terrestrial hazards whose impacts are often exacerbated by taking place in areas with high economic and

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social vulnerabilities (Hildebrand and Norrena, 1992; Fleischhauer *et al*, 2005).

In the Western Mediterranean, beaches have been the most valuable asset for many tourist destinations on the coast over the past decades, even inspiring the term "sun and sand tourism" (Sardá *et al*, 2009). This started in the 1950's and reached its maximum during the 1970's, when land occupation achieved saturation levels and tourism carrying capacity has been attained or even exceeded in some areas. In Catalonia, tourism represents almost 10% of the Gross Domestic Product (GDP), being the main economic activity in the area (Valdemoro and Jiménez, 2006). However, this excessive development and the associated infrastructures, which support tourism industry, have been identified as one of the main factors inducing coastal degradation (Wong, 1998; Sardá and Fluvià, 1999). On the other hand, natural processes and natural hazards (*e.g.* coastal storms, coastal erosion and dangerous marine life) have been also identified as important factors affecting beach exploitation.

On Mediterranean beaches, regional climatic conditions determine the intensity of the interactions between coastal dynamics and beach uses, and hence the supply of these services (*e.g.* services provided to tourists) (Valdemoro and Jiménez, 2006). Within the last decades the number of natural hazards world wide has been increased by a factor of 2.2 as compared to the 1960's, and their damages have been increased exponentially (*e.g.* economic losses increased by a factor of 6.7), showing a trend that the Intergovernmental Panel on Climate Change (IPCC) suggests is not going to stop in the near future (Pérez-Maqueo *et al*, 2007; Raschky, 2008).

Traditional beach management has had a 'hazards-and-playgrounds' view of beaches, being concentrated on geomorphic hazards and beaches recreational uses, overlooking their ecological and broader environmental values (James, 2000). In Spain, the effort of beach managers has also been focused mainly on the recreational function, leading the natural and protective functions to a secondary level (Ariza *et al*, 2008a). Actually, it is recognized that human activities and the ecosystems in which they occur should be managed as a whole. This outlines the fundamental basis for the Ecosystem Approach and has resulted in the emergence of the concept of social-ecological systems, reflecting the inextricable link between society and ecology.

There is clear evidence that beach management must be integrated, well coordinated and based on interdisciplinary approaches (Cheong, 2008).

Risk Analysis is internationally recognized as an approach to assist decision making. It is a systematic tool intended to provide decision-makers with an objective, repeatable and documented assessment of the risks posed by a particular course of action.

A risk-based approach also helps managers to prioritize issues and focus efforts when regulating the activities which are considered to have the greatest potential impact (Hardy and Cormier, 2008). However, as coastal management, traditional risk management also overlooks beaches environmental values, focusing on damages to assets and not considering the total risk in management (Meyer *et al*, 2009). Coastal and risk management requires a systemic vision, encouraging synergies between all interests (*i.e.* policies, sectors and individuals) and considering both natural and socioeconomics variables (Forst, 2009).

In response to the need to incorporate integrated and proactive tools which assist coastal managers, this paper applies a beach multi-risk assessment methodology in a touristic beach in the Costa Brava (Spanish Mediterranean). This methodology, which still is under development, allows the prioritization of the most risky hazards and the most affected ecosystem services, helping the manager to decide where to allocate resources to cope with natural and anthropogenic induced hazards affecting beach's functionality.

MATERIALS AND METHODS

Study Site

The Costa Brava is located in the north-eastern part of the Catalan coast. This area presents a highly indented coastline, mainly composed of cliffs, especially in its northern zone, where bayed and pocket beaches are the dominant beach type (Valdemoro and Jiménez, 2006).

Within the Costa Brava, the multi-risk assessment has been developed in S´Abanell beach, an important summer touristic destination at the southern part of the Costa Brava (Girona province) which suffers different coastal hazards and provides several ecosystem services. Two different zones have already been described for this urban beach in terms of frequentation, beach uses, hinterland, morphodynamic and management (Valdemoro and Jiménez, 2006).

The Southern zone goes from the Tordera River delta up to 900 m to the north, including the emerged zone of the northern hemi delta. This area presents a slightly urbanized hinterland, which includes natural areas (Red Natura 2000), croplands and camping areas. Recreation is the main use, as in the entire beach, but even during the bathing season this use is not very intense. Nevertheless, in the Northern zone beach frequentation is certainly greater especially during the bathing season, which is intimately related to the urban hinterland that characterizes this zone, being one of the main touristic beaches in Blanes town. These differences along the beach increase the interest of this social-ecological system as a study case (Figure 1).

Methodology

In order to perform the risk prioritization in S´Abanell beach, we start with the identification and characterization of both main coastal hazards and main ecosystem services provided by this social-ecological system. Coastal hazards

were identified and then characterized based on the most relevant Pathways of Effects (PoE) which hold them, defining their main impacts. Based on the DPSIR model, a PoE has been defined as "a representation of conceptual models which illustrate the relationships between the potential cause of a hazard and the endpoint impact which could occur" (Hardy, 2008).

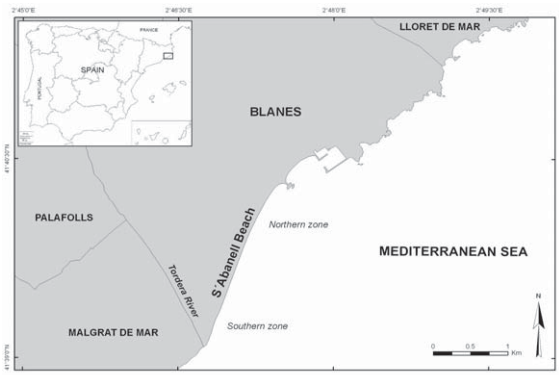

Figure1. Map of the study zone, showing the S´Abanell beach at the beginning of the Costa Brava (Blanes Municipality) in the Mediterranean Catalan coast. The two zones (*i.e.* Northern and Southern) identified along this beach are also presented.

The ecosystem services were characterized considering the features of the beach and their main activities, including their main vulnerabilities. Combining both characterizations, we obtained the Beach PoE which links coastal hazards and ecosystem services by their main impacts and their main vulnerabilities, respectively.

Then, following these linkages defined in the Beach PoE, the risk has been valuated as the product of hazard, exposure, and consequence (Morrow, 2009). In this case the risk has been calculated as the product of the hazards intensities and the economic valuation of the affected ecosystem services, assuming that the exposure is maximum and constant along the entire beach.

The hazards intensities (H) have been obtained based on their frequencies and consequences according to probability distributions or historical data, which consider a return period or a temporal scale previously defined for each hazard (see Table 1).

Concerning the ecosystem services (S), their economic valuations (Ecosystem Service Value, ESV) have been obtained applying the transfer value method, being aware of its limitations (*i.e.* biophysical and socio-economic sensitivity) but also of its advantages when ad hoc estimations were not available (Troy and Wilson, 2006).

Based on the linkages defined in the Beach PoE, the risk values have been calculated per each hazard (1), each ecosystem service (2), and for the entire social-ecological system (3):

$$\mathbf{R_H} = \sum_{S=1}^{S=n} \left(\mathbf{H} \times \mathbf{ESV_S}\right) \quad (1)$$

$$\mathbf{Rs} = \sum_{H=1}^{H=n} \left(\mathbf{H} \times \mathbf{ESV_S}\right) \quad (2)$$

$$\mathbf{R_T} = \sum \mathbf{R_H} \text{ or } \sum \mathbf{R_S} \quad (3)$$

Table 1: *Main hazards identified and quantified in S´Abanell beach. The proxies used to quantify these hazards and the calculated intensities (H, from 0 to 1) for both zones of S´Abanell beach (N: Northern and S: Southern) are also presented. (*) Good water quality and Low concentration of jellyfish have been defined by the Catalan Water Agency (ACA).*

Hazards	Proxies	Intensity	
		N	S
Pollution	Frequency of *Good water quality* during the bathing season (*)	0.2	0.0
Human uses	Hinterland urbanization (% natural, semi-natural or urban land covers)	0.6	0.2
	Tourism overuse (sand availability, $m^2 \cdot user^{-1}$)		
Jellyfish	Frequency of *Low concentration* during the bathing season (*)	0.0	0.2
Long term erosion	Erosion rate (5 yrs period) vs. beach width	0.0	0.0
River flood	Extreme probability distribution of floods (Tr=50 yrs) vs. river bank height	1.0	1.0
Storm-induced erosion	Extreme probability distribution of beach induced retreats (Tr=50 yrs) vs. beach width	0.0	1.0
Storm-induced flood	Extreme probability distribution of water level increase (Tr=50 yrs) vs. beach sea front height	0.8	1.0

Finally, a risk score has been calculated to facilitate risk prioritization. For each hazard the score has been obtained as the ratio between the total risk of the hazard (R_H) and its maximum possible risk (i.e. maximum hazard intensity affecting all the ecosystem services). For the ecosystem services, the score has been determined as the ratio between the total risk suffered by the ecosystem service (R_S) and the ecosystem service value (ESV_S). Considering further possible comparisons with another beaches, the risk score for the entire system has been calculated as the ratio between the total risk (R_T) and the maximum possible total risk (*i.e.* maximum hazard intensity affecting all the ecosystem services).

RESULTS

Seven hazards have been identified and quantified in S´Abanell beach, being both anthropogenic (pollution and human uses) and natural/climate related (jellyfish, long term erosion, river flood and coastal storm, separated in storm-induced erosion and storm-induced flood). Based on the DPSIR model and considering the framework and the objectives of this analysis, two PoEs holding these hazards have been obtained, identifying two possible impacts: beach surface reduction and beach quality reduction (see in Figure 2).

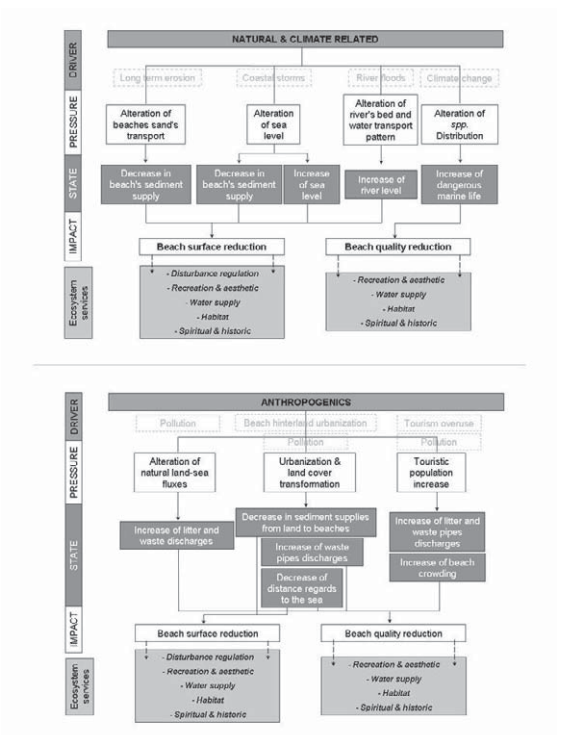

Figure2. Beach Pathways of Effects obtained for S´Abanell beach based on the analysis of both hazards (main impacts) and ecosystem services (main vulnerabilities), following the DPSIR model.

Concerning the quantification of these hazards, in the Northern zone river flood, storm-induced flood and human uses (in decreasing order) were the most intense hazards, while in the Southern one Storm-induced erosion presented a higher intensity than human uses (Table 1).

Considering the features of S´Abanell beach, and its condition of urban and important touristic destination intensively used during the bathing season, five ecosystem services have been identified and characterized: Disturbance regulation, Recreation & Aesthetic, Water supply, Habitat, and Spiritual & Historic. Bearing in mind the hazards impacts described in the PoEs, and considering the ecosystem services as receptors of these impacts, beach surface and beach quality reduction were analyzed as possible vulnerabilities of the identified ecosystem services (Table 2). Concerning the economic valuation (ESV: €·ha^{-1}·yr^{-1}, standardized to the average 2009 Euro), Disturbance regulation (95,165 €·ha^{-1}·yr^{-1}) was the most valued service, while Spiritual & Historical (83 €·ha^{-1}·yr^{-1}) was the one which presents the smallest economic value (Table 2).

Table 2: *Main ecosystem services identified and characterized in S´Abanell beach, including a description considering the differences along the beach under study (N: Northern and S: Southern) and their main vulnerabilities. The results of the economic valuation of each ecosystem service (Ecosystem Service Value, ESV) are also presented.*

Ecosystem services	**Description**	**Vulnerability**	**ESV** (€·ha^{-1}·yr^{-1})	**Supply** (%)	
				N	**S**
Disturbance regulation	Urban beach	Surface	95,165	100	72
Recreation & Aesthetic	Touristic beach	Surface - Quality	69,577	100	15
Water supply	Desalinisation plant	Surface - Quality	25,920	-	100
Habitat	Red-Natura 2000	Surface - Quality	106	-	100
Spiritual & Historic	Costa Brava	Surface - Quality	83	100	100

Nevertheless, the already explained differences between the two zones of S´Abanell beach (*i.e.* beach use, management, and frequentation) were considered in this characterization and a percentage of supplied service was defined for each service in each zone. The main differences between these zones occurred in disturbance regulation and, recreation and aesthetic services, due to the differences in the beach hinterland and the recreational use, respectively. Based on GIS analysis, the Northern zone presented a beach hinterland 18% more urbanized than the Southern one and that is why the latter supplies 72% of disturbance regulation service.

Concerning the recreational and aesthetic service, the recreational use in the Southern zone is 85% smaller than in the Northern (*sensu* Roca et al. 2008), explaining the 15% supply of the recreation and aesthetic service in the Southern zone. Water supply and habitat services presented 0% in Northern zone because they were just identified in the Southern one, being strictly associated to the infrastructures of a desalinisation plant and to the Tordera River delta (Red Natura 2000), respectively. These percentages of supplied service were also applied for the risk estimation, adapting for each zone the general economic valuations (ESV) presented in Table 2.

Based on the characterization of both hazards and ecosystem services, and combining their impacts and vulnerabilities following the DPSIR model, we obtained the Beach PoE for S´Abanell beach (Figure 2). Finally, following the obtained Beach PoE and combining the hazards intensities and the economic valuation of the ecosystem services, the risk values and the corresponding risk scores were calculated for each hazard and each ecosystem service for the two zones of S´Abanell beach. In the Northern zone, River flood was the most risky hazard, followed by storm-induced flood and human uses, while in the Southern zone the three riskiest events were river flood, storm-induced flood and storm-induced erosion (Figure 3).

Concerning the ecosystem services, recreation and aesthetic and spiritual & historic were the most affected in the Northern zone, while in the Southern one recreation & aesthetic was the most affected ecosystem service. Considering the two zones of S´Abanell beach, the Southern one presented a higher risk score than the Northern one (Table 3).

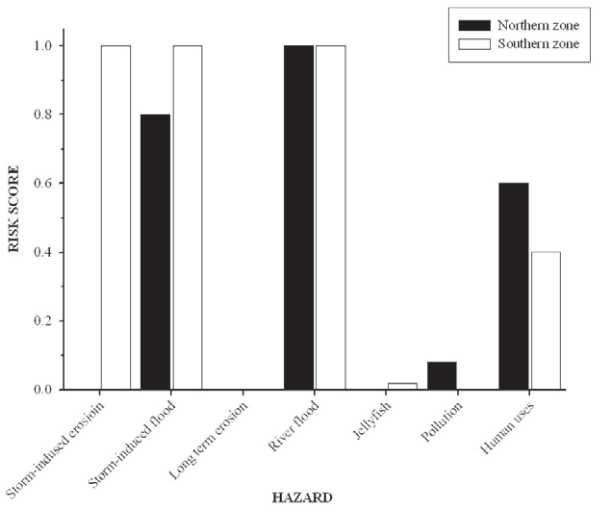

Figure3. Risk scores (from 0 to 1) calculated for the seven hazards identified in S´Abanell beach. The results are presented for both Northern and Southern zones of the beach..

Table 3: Risk valuation results for each ecosystem service in each zone of S´Abanell beach, showing both risk values (R_S) ands risk scores (Score).

Beach zone	Ecosystem service	R_S	Score
Northern	Disturbance regulation	913,584	2.4
	Recreation & Aesthetic	723,601	2.6
	Spiritual & Historic	863	2.6
	Total	*1,638,048*	*2.5*
Southern	Disturbance regulation	1,081	3.4
	Recreation & Aesthetic	795,960	3.6
	Water supply	264,384	3.4
	Habitat	112,715	3.4
	Spiritual & Historic	847	3.4
	Total	*1,174,987*	*3.4*

CONCLUSIONS

This paper applies a beach multi-risk assessment methodology with the aim to help coastal managers decide where to allocate resources to cope with natural and anthropogenic induced hazards affecting the beach's functionality.

Even if it is under development, this tool identifies and prioritizes the most risky hazards and the most affected ecosystem services supplied by the beach, allowing planning ad-hoc management processes, improving beach and coastal management.

The inclusion of the economic valuation of non-market services in the risk assessment should also ameliorate traditional risk analysis, providing managers with additional information, and improving decision-making in an integrated coastal zone management process.

The riskiest hazards in S´Abanell beach were River flood and Coastal storms, being the latter composed by Storm-induced flood and Storm-induced erosion. This risk prioritization is in accordance with the RISKCAT program (Natural Risks in Catalonia), one of the few risk analysis performed along the Catalan coasts, which describes the Tordera River delta zone as a high risky river flood area, and a high danger zone related to coastal erosion and coastal flood (Generalitat de Catalunya, 2008).

Within the S´Abanell beach, the Southern zone has been the riskiest zone based on the applied methodology, presenting a

higher risk score than the Northern one. Although any causality analysis does not exist, this result matches with the consequences observed in the Blanes sea front during the extreme storm events in 2008 and 2009. Even if the Northern zone suffered several damages during these storms, the consequences in the Southern zone were worst, part of the sea front was destroyed, and the beach was strongly altered and extremely eroded.

In the Northern zone human uses was one of the three most risky events, while in the Southern one River flood, Storm-induced erosion and Storm-induced flood were the riskiest. These results are in accordance with the strong differences in beach hinterland's urbanization and recreational uses already described between both zones.

The northern beach has almost 100% of its hinterland urbanized, which is mainly composed by hotels, camping areas and private properties. As a consequence, the northern zone of S´Abanell beach is maybe the principal touristic beach in Blanes town, offering good touristic services and facilities (e.g. beach guarding, showers, umbrellas and hammocks), but suffering important crowding levels during the bathing season (Roca *et al*, 2008; Ariza *et al*, 2010).

Based on the applied methodology, recreation and aesthetic and, spiritual and historic were the ecosystem services more affected, though scarcely in front of habitat, disturbance regulation and water supply. This ecosystem service prioritization results are critical for S´Abanell beach's management, considering that this beach is an important tourist destination, mainly managed to guarantee this industry (Valdemoro and Jiménez, 2006).

Even if it is under development and additional work is required, this tool should provide a procedure to obtain a systemic and spatially explicit coastal risk assessment, improving risk analysis and helping managers to make responsible decisions in an integrated beach management process.

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