The Influence of Shoreline Dynamics on the Use and Exploitation of Mediterranean Tourist Beaches

HERMINIA I. VALDEMORO and JOSÉ A. JIMÉNEZ

Laboratori d'Enginyeria Maritima, ETSECCPB, Universitat Politècnica de Catalunya, c/Jordi Girona 1-3, Campus Nord ed. D1, 08034 Barcelona, Spain.

Fax: 34 93 4011861, E-mail: herminia.valdemoro@upc.edu, jose.jimenez@upc.edu

Abstract

The potential influence of shoreline dynamics on beach use and the exploitation of beaches for recreational purposes is analysed for the Mediterranean coast. This is done by assuming that for intensively-used beaches, such as those considered in this work, beach carrying capacity is mainly influenced by the available subaerial surface. In mid-latitude areas with well-defined climatic seasons, managers will need to know the optimum configuration for the beach's recreational purposes in May at the latest if they are to properly plan the services for users during the bathing season. This can be affected by three main aspects of shoreline dynamics: long-term erosion, shoreline reorientations in bayed beaches and storm-induced changes. To analyse the influence of these processes, here we introduce the concept of "optimum beach width", which is the value ideally used by visitors when no spatial constraints exist. The effect on this width by each of the mentioned processes is discussed by using examples taken from Spanish beaches.

Keywords: beach management, beach recreation, beach erosion, tourism, carrying capacity.

Introduction

Spain and the north eastern Spanish region of Catalonia (Figure 1) are traditional tourist destinations for western Europeans. The importance of tourism for the Spanish economy is clearly reflected in its contribution to the GNP which, in the case of Catalonia, was 9.9% in 2001 (Generalitat de Catalunya, 2002). The importance of coastal tourism in particular can be clearly appreciated when we consider that most tourists choose to stay in coastal areas. In 2001, for example, 65% of foreign tourists in Catalonia chose the coastal area as their first destination (Generalitat de Catalunya, 2002). These figures exclude the city of Barcelona which by itself attracted 30.6% of foreign visitors. Because of this, the coastal region has undergone intense urban and tourist development. Mainly, this started in the 60's and reached its zenith during the 70's. As a consequence, land occupation in some areas has clearly reached saturation level in such a way that such areas have attained the stagnation stage in the tourist cycle of evolution. This has been reflected in the fact that these areas have reached the peak number of visitors and capacity levels for many variables have been also reached (see e.g. Priestley & Mundet 1998). This means that in some places the tourism carrying capacity (TCC) has been attained or even exceeded. TCC can be defined as the maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic and socio-cultural environment and an unacceptable decrease in the quality of visitor's satisfaction (PAP, 1997).

This excessive development of resorts, as well as the associated infrastructure to support the tourist industry in coastal areas, has become one of the main elements affecting the quality of the coastal environment and it has been identified as one of the main factors inducing coastal degradation (Smith 1991; Wong 1998; Sardá & Fluvià 1999). An overview of the coastal tourism-environment relationship with examples from UK can be seen in Jennings (2004).

An order of magnitude of the pressure exerted on the coastal region during this process can be obtained by estimating the occupation of the land surface by urbanized areas (MMA, 2001). In the area of study, the Landscape Analysis and Management Laboratory of the University of Girona has analysed the changes in land use in the coastal municipalities of the Costa Brava between the years 1957 and 2003 (Martí & Pintó, 2004; Nogué, 2004). This period covers the tourist boom in Spain and, changes in the use of the territory should reflect this pressure. During this period, the urbanized area increased from an original 2% of the territory to the 13 % in 2003 that in absolute terms mean an increase from 1127 ha in 1957 to 8810 ha in 2003 (Martí & Pintó, 2004). Some implications of this occupation on the status of the Spanish coastal zone can be found in Mávarez-García et al. (2000), Sardá et al. (2005) and Suárez de Vivero and Rodríguez-Mateos (2005) among others.

During the initial phase of the development of the Spanish coastal tourist industry the main exploited resource, the beaches, were not experiencing significant stability problems (or at least not any visible problems) and, in consequence, the planning of capacity, infrastructure and services was mainly done without considering any possible change in the beach configuration. While beach status did not affect beach exploitation, there was a lack of awareness about the influence of natural processes. As these began to interfere with beach use and/or services to be provided to users and tourists, corrective measures of different nature had to be taken to prevent or mitigate a change in the carrying capacity of the beach.

In its most general form, beach carrying capacity refers to the amount and type of visitor use that can be accommodated within a given amenity area (the beach) without unacceptable social consequences and without a negative impact on resources (adapted from Manning & Lawson, 2002). This carrying capacity is equivalent to the above introduced TCC but applied to a given environment or part of the territory, the beach. Two main aspects are usually included in the assessment of the recreational carrying capacity. These are the biophysical component, which refers to the integrity of the resource base and the behavioural component, which addresses the quality of the recreational experience (Sowman, 1987; Wall 1982; Saveriades, 2000). In beaches subjected to intensive use, the biophysical component is mainly restricted to physical factors. Environmental values are not treated as a high priority, and when they are considered it is in terms of the landscape. On the other hand, behavioural factors are less restrictive than in very natural environments since users' requirements are basically limited to a clean beach (water and sand), services, access and available area (see e.g. Pereira et al., 2003).

In these coastal environments, the recreational experience (apart from water and sand quality) strongly depends on beach dimensions. These will determine the surface available for users and the services which can be provided. In addition, beach size will be the main variable affecting the beach users' perception of crowding. Since the subaerial surface is a dynamic feature in the sense that beaches continuously react to marine forcing, coastal dynamics should play a significant role in determining beach use and exploitation.

Within this context, the main aim of this paper is to discuss and analyse the potential influence of shoreline dynamics on the use and exploitation of typical, intensively-used Mediterranean beaches. Although the paper uses the Catalan beaches of north eastern Spain to illustrate the analysed processes, the comments about them can be extrapolated to most of the Mediterranean coast or to similar beaches in other regions of the world.

Mediterranean Beaches of Intensive Use

Beach Types

The area of study selected in this work to illustrate the effects of coastal dynamics on beach use is the Catalan coast (Figure 1). Catalonia is located in the northeast Spanish Mediterranean, and it has a coastline of about 699 km long which is formed by a large diversity of coastal types such as cliffs, large bays, pocket beaches, long straight beaches and deltas. These environments present a more or less well-defined spatial distribution in such a way that each coastal province presents a dominant beach type. Thus, from North to South we can identify five main areas:

- Costa Brava (Girona) which is a highly indented coast with most of the coastline composed of cliffs, especially in the northernmost area. Bayed and pocket beaches are the dominant beach type, with most of them composed of coarse and medium sands.
- Maresme (Barcelona) which was originally a straight and uninterrupted sandy coast extending from the Tordera delta in the North to the city of Barcelona in the South. Now this coast is artificially divided into six cells following the construction of five marinas.
- The southern Barcelona coast, located southwards from Barcelona Harbour. It comprises the Llobregat delta and associated beaches that extend from the Llobregat river to the Garraf cliffs forming an uninterrupted fine sand coast about 15 km long.
- Costa Daurada (Tarragona), is composed of different beach-types, ranging from long, straight beaches to pocket beaches, all of them composed mainly of fine sands.
- The Ebro delta, located to the south of Tarragona and formed by the deposits of the Ebro river, with a 50 km fine sand coastline.

In addition to these areas, it is also common to find some parts of the coast significantly engineered in such a way that they can be classified as artificial coasts or beaches. These are usually located in severely eroded areas. An example of these artificial coasts is the Barcelona city waterfront which is formed by a series of beaches created for the 1992 Olympic Games

(Peña & Covarsi, 1994). This waterfront has been extended towards the north, with more beaches and a marina, within the framework of Barcelona's 2004 International Forum of Cultures. In both cases the creation of beaches was a part of an ambitious urban development plan which involved significant waterfront rebuilding.

In this study, we focus on the most frequently used and exploited coasts that have as a main common characteristic the fact that that they are intensively used. This means that they are restricted to beaches with the following profile:

- They are heavily used only during the bathing season, which is in the summer.
- They are located in well-accessed areas, and in most cases are urban beaches.
- They are mostly relatively narrow beaches and are backed by waterfronts.
- They support (or have) services for beach users.
- They are essential for the local economy in terms of tourism and second residence properties.

These beaches are usually characterised by a limited available area per user in such a way that, in some cases or in some periods, they can be close to saturation level. This corresponds to an overcrowding situation with density of users reaching values characteristic of an unpleasant recreational experience. In Spain, a typical mean value for the available surface per user at saturation level for intensively-used beaches is about 4-5 m^2/user (MOP, 1970; Alemany, 1984), although it is also accepted that this density can be exceeded on some days during the height of the season. However, Yepes (1999) analysing the exploitation of some tourist Mediterranean beaches found that they are only comfortable when the available surface per user is larger than this value of 4-5 m^2/user and, only considering the active and resting areas of the beach (see next chapter). In any case, the available beach surface per user is usually directly related to the quality and price of the tourist services in the area and, in consequence, will influence the TCC in beach tourist destinations A very low available surface per user is typical of mass tourism areas, with reported values between 5 and 25 m^2/person (de Ruyck et al., 1997; PAP, 1997).

Beach Zonation

When considered in terms of its recreational purposes, a beach can be divided into four zones in the across-shore direction (MOP, 1970): the active, the resting, the safe and the service zones (Figure 2). The *active or immersion zone* is the area around the waterline. It must be free of any static element although in some areas materials required for nautical sports may be permitted in this zone. This is the transition area between the subaerial beach and the water.

The *resting zone* is the area where most beach users are found and, in consequence, where umbrellas and sun-beds are usually placed. Normally this area does not include any services, unless the beach is too narrow.

The *service zone* occupies the most landward part of the beach, and it is the area where installations and services for beach users such as showers, dressing-rooms and bars are located. In relatively wide beaches an additional area can also be considered; this is the *safe zone*, which acts as a buffer area between the resting zone and the service zone. This area accommodates users when the rest of the area is not adequate for the purpose.

The dimensions of each area depend on the actual beach width, and typical values for Spanish beaches are given in Table 1 for wide beaches (wider than 50 m) and narrow beaches (narrower than 50 m). A similar zoning has been adopted by Polette & Raucci (2003) in a carrying capacity analysis on Brazilian beaches, although they adapted their research to the local specifics of beach use.

Although it could be argued that the resting zone should be as wide as necessary to accommodate users comfortably, this is not a strictly valid argument. Thus, in the

Mediterranean coast, this area is usually restricted to the dimensions shown in Table 1 in such a way that, in most cases, users prefer to stay closer to the waterline in a crowded zone instead of dispersing widely over the beach surface. Figure 3 shows a very wide pocket beach in Costa Brava (sa Riera beach, Girona). It can be clearly seen that there is a concentration of users in the resting zone while a large part of the beach is only used as access to that area. In fact, local users of this beach have identified the excessive width of the beach as the main problem in the area (Jiménez & Sánchez-Arcilla, 2001). Users justify this behaviour by citing the fact that sand gets very hot on sunny days, and walking across large areas of the beach is uncomfortable. Villares (1999) analysed the views of users of some Catalan beaches, and she found that they strongly criticised the excessive width of some nourished beaches; and in a recent survey by CEDEX (2000) it was found that users of various Spanish beaches gave a negative score to beaches wider than 50 m. However this "crashes" with the actual general design of nourished beaches in which beaches about 100 m wide are usually created to meet 10-15 year lifetime targets.

This spatial distribution of users on the beach can be significantly affected when the beach surface is exploited through beach concessions as the "bagnos" (baths) in many Italian beaches. In essence, the "bagno" is an administrative concession of a part of the beach, and it allows the concession-holder to supply some services to the beach users at a cost. These services are normally contracted for the full season, and essentially consist of a section of the beach surface with sun beds and umbrellas. In this way and opposite to the public beaches described previously, the spatial distribution of users across the beach is almost uniform, and with the exception of very wide beaches, the entire subaerial beach surface is exploited.

This spatial distribution of users will be modulated by the varying water level in the case of meso and macrotidal areas, since the emerged beach will vary according to the tidal stage.

The Influence of Shoreline Dynamics

General Aspects

Regional climatic conditions determine the intensity of the interaction between coastal dynamics and beach use on Mediterranean beaches. In years during which there are typical weather conditions, there is a time lag between beach use and incoming wave energy. In practical terms, this means that the season with the highest beach occupation (the summer, normally from June to September) is the period with the lowest wave energy, while the period with the highest wave energy usually occurs during periods of very low beach use. This is illustrated in Figure 4 for the Catalan coast, which shows the number of tourists per month in 2001 as an indication of beach use and the average significant wave height as representative of wave energy.

It is clear from this that if we only consider the beach's recreational function, then the period in which the beach has to be at its optimum is the summer, since this is the period of highest use. In fact, this configuration should be established some time before the start of the season in order to properly plan and prepare the services that are required, such as sun beds, parasols, public toilets, showers, bars and so on. In Spain, most of these services are temporary, and once the bathing season ends they are removed until the next season. Only a few services, such as the showers, can be permanent features. These services, along with the activities that take place on the beach, are regulated on a yearly basis by the municipal authorities and are subject to the approval of the General Directorate for Coasts (Ministry of the Environment).

If the principal priority is to ensure the protection and safety of the hinterland, the beach should be at its optimum during the months with the highest wave energy content. This optimum condition may be different from the one that applies to a beach for which the principal priority is its recreational function. This should consist of a beach wide enough to dissipate/absorb wave energy during storm impacts in such a way that infrastructures in the back of the beach will be protected from direct wave impacts.

Long-Term Erosion

The most obvious major influence will occur when coastal dynamics acting on a specific stretch of the coast causes the beach to be eroded resulting in a progressively narrower beach. Here we specifically refer to long-term erosion which can be caused by factors such as alongshore gradients in longshore sediment transport. The influence of this process in beach recreational carrying capacity has been analysed by Withmarsh et al. (1999) among others. They found that beach visitors attached a positive monetary value to their recreational enjoyment, and that they expected this value to decrease as a consequence of erosion. However, when substitute beaches were available within the area, users did not necessarily perceive coastal protection measures taken on eroded beaches to be of great benefit (Silberman & Klock, 1998). In any case, when erosion is severe enough to prevent the existence of a beach with an adequate width (for recreational and safety purposes), inland developments (resorts and/or second residences) are severely restricted or are absent (Valdemoro et al., 2002).

Figure 5 illustrates the potential influence of long-term erosion on the beach surface that is available for recreational purposes per user. To simplify the analysis, it is assumed that the number of beach visitors is constant. Two main cases are considered in function of the initial beach width, i.e. wide and narrow beaches. Wide beaches are those wider than an optimum width, s_o, which corresponds to the value comprising active+resting+safe areas when no spatial restriction exists (see values in Table 1), and narrow beaches are those narrower than the optimum width. Here, the limiting value in the lowest range is called the saturation width, $s_{s,}$ which is the value corresponding to a beach configuration in which the user density will reach the saturation value, i.e. 5 m^2/user. This value may vary depending on the site.

On beaches wider than the optimum width, although erosion reduces the total surface available per user, the area used is not affected since the used strip of beach will be displaced landwards following the shoreline retreat (Zone A in Figure 5).

Once the beach width falls below the optimum value, the shoreline retreat is accompanied by a reduction in the available and used beach widths, which results in an increase in user density (Zone B in Figure 5). In terms of recreation, there will be a lower limit or final stage during which the beach has reached the saturation level. Any further reduction in the surface, despite the fact that this will reduce the surface available, will not affect user density because this will have already reached its maximum physical value (Zone C in Figure 5). This limit value will be maintained by a decrease in the number of visitors because there will be no room to accommodate a steady influx.

In terms of tourism planning, this process is likely to affect the potential exploitation of the area, since a change in beach surface availability not only influences user density but also the user's profile. To evaluate this influence, a relationship between the type of user and the beach's characteristics (among others factors that have an affect on a tourist's enjoyment of the beach) should be established. An example of this is the existing range of beach surface required per user, which is linked to the quality of the resorts in the area (PAP, 1997). Thus, a change in the visitor's profile will also imply a change in the associated tourist industry and potentially would affect the Tourism Carrying Capacity of the area.

This interaction model has been applied to the s'Abanell beach, a 2.5 km long sandy beach located in Blanes (Costa Brava, Figure 6). This beach can be zoned into two areas corresponding to the urban development of the hinterland and its accessibility: (i) a northern urban area, about 1.5 km long, with a promenade running along the back of the beach with an access point to the beach every 35 m and (ii) a southern semi-urban area, about 1 km long, where the hinterland is occupied by camping areas in which there are no access points along the southernmost 500 m. This spatial variation in the properties of the hinterland is clearly reflected in the degree of beach use, with the northern area being intensively used whereas the southern area has a much lower density (Figure 6).

Figure 7 shows the long-term shoreline evolution of the s'Abanell beach from 1957 to 2004, which was calculated by applying linear regression by least mean squares to measured shorelines. It can be seen that after a period of accretion, the evolutionary trend of the beach changed in the 70s and it is now an eroding coast (Jiménez et al., 2002). This change in the beach's behaviour has been associated with a drastic decrease in riverine sediment supplies from the River Tordera due to major dredging operations on the river bed (several million m^3 of sand were extracted from the river bed for construction in the 70s) as well as to a decrease in river liquid discharge (Jiménez et al., 2002). This decrease in sediment supplies has led to a reshaping of the Tordera delta by wave-induced currents, which means that the delta no longer plays a role in dynamically maintaining the beach at its southernmost end. Thus, the beach is being eroded as a result of a gradient in the net longshore sediment transport, which is directed towards the south due to the dominance of eastern waves in the area (Jiménez et al., 2002).

In spite of this general behaviour, long-term shoreline rates of displacement vary along the beach (Figure 7). There are two well-defined areas: a northern area in which erosion rates are very low and a southern area close to the delta in which erosion rates are very high. This means that the expected evolution of the beach width will vary greatly alongshore, in such a way that, according to the estimated rates, the southern area will experience far greater problems related to width decrease than the northern area, in which there will be little width decrease, if any. To give an idea about the initial state of the beach (measured in May 2004), the overall average width was about 29 m whereas the average widths for the southern and northern areas were 16 m and 35 m respectively.

The starting level of use of the beach was taken from the only systematic study that exists on the use of Catalan beaches, which was carried out in the first week of August 1982 (high season) by Alemany (1984). This study reports an used surface value of 8.7 m^2/user for the s'Abanell beach, with users concentrated on a 30 m wide fringe along the shoreline. In the framework of the MeVaPlaya research project, Riera (pers. comm.) measured the use of the beach under present conditions (summer 2004) and she found that the urban part of the beach had a representative value of about 8.1 m^2/user, whereas in the southern part the area that is available per user is about 3 times greater.

The evolution of the density of users in the urban area of the s'Abanell beach since 1983, according to the model presented above, is shown in Figure 8. Since there is a clear difference in the level of use and shoreline behaviour in the northern and southern areas of the beach, the evolution of the density of users was calculated separately for the two areas. For the southern beach, the starting value of the surface available per user was taken to be 3.4 times greater than that of the northern area (although no data is available for that date, we applied the same occupation rate as that which is currently applicable). In addition to this, two scenarios were considered in our analysis of the evolution of beach use, the first of which assumes that if the evolution of the available beach surface in the southern area affects local users, they will move to another area and not to the urban area, i.e. the two areas act as independent beaches. The second scenario assumes that if the southern area is affected in a way that leads local user density to exceed the density in the northern area, users will relocate towards the urban beach. To be consistent with the data used for user density, it is assumed that users concentrate in a

30 m wide active+resting area, in such a way that any change in local conditions resulting in a beach wider than this value will not affect user density.

Figure 8 clearly shows the different evolution in beach use experienced by the two areas of the beach. The southern area presents a slight increase in user density from 1982 to 2000. However, from 2000 onwards, the estimated area that is available per user decreases dramatically, in such a way that after 2012 the density of use in this part of the beach will exceed that corresponding to the northern area. This difference in rates of change in the density of users was due to the fact that, initially, although shoreline erosion was significant, the initial beach was wide enough to "absorb" it, but as erosion continued, the remaining beach width became significantly narrower than the optimum value of 30 m.

The evolution of user density in the northern area was more or less stable between 1982 and 2004. During this period, the area available per user only decreased by about 4%. For the remaining period (2004 to 2030), the area available per user has decreased slightly, although at a much lower rate than in the southern part. This difference in the evolution of user density in both areas of the beach is due to the fact that erosion rates in the southern part are significantly higher than in the northern one (Figure 7). As a result of this, if we consider the evolution of beach use for the northern area independently from that of the southern area, the beach will be able to maintain a reasonable user density for more than 30 years. However, if we consider the transfer of southern beach users to the northern part once the local density exceeds the value of the latter (it is predicted that this will occur in 2012), the area available per user will significantly increase after that date and the beach should reach the saturation level (5 m^2/user) in about 2024.

This estimate must be considered in the context of assumed hypotheses, i.e. that the number of users will remain constant and that there will not be a change in long-term shoreline evolution rates over the next 30 years. The first hypothesis implies to consider the site to be at the mature stage according to the lifecycle model of Hovinen (2002). This is in agreement with the almost constant density of users observed from the end of 80's until now as it was mentioned above. The second hypothesis implies that coastal dynamics in the area and boundary conditions will not significantly change during the next decades. In any case and as it is introduced later in the paper, an effective beach management strategy must include a monitoring program for natural and human processes in the beach to adapt the management to the real situation.

Shoreline Fluctuations in Bayed/Pocket Beaches

One of the most common characteristics of bayed and pocket beaches is that they are usually in long-term equilibrium in terms of sediment volume. This results in typical morphodynamic behaviour with shoreline fluctuations following changes in the direction of incident waves.

When shoreline reorientations are extreme, part of the beach disappears, with most of the sediment being transported and deposited to one or the other end of the beach. Although this means a redistribution of sediment rather than a loss, it may significantly affect the beach's exploitation.

Here, "extreme reorientations" refer to shoreline changes resulting in the local disappearance of the beach at one end in such a way that, although the beach surface that emerges remains stable, shoreline length decreases. In this situation, although the beach surface that is available per user should not be affected (assuming that no sediment losses take place during the process), the length of shoreline that is available per user will decrease because users will congregate on one part of the beach.

An example of this process can be seen in Figure 9, which shows the shoreline configuration of the Lloret de Mar beach (Costa Brava) in May 2004 superimposed on a typical summer configuration (July 2000). As can be seen, the western end has a large surface area, while the eastern end largely lacks sand; as a result, most users will have to congregate at the western end. This is clearly a problem since this is a beach whose user density is close to the saturation value: the area available per user as measured in August (peak season) is about 5 m^2/user. Thus, all these users will have to move to a very wide beach, which forces them to occupy the innermost part of the beach. Although the concentration of users at the back of the beach will allow the beach to "absorb" this concentration, if we calculate the ratio of users per shoreline length the number will increase drastically. This means that, on this part of the beach, the water surface will be overcrowded and the beach services will be insufficient for the number of users. In addition to this, accesses in the Northern part of the beach (along a 200 m stretch) are non-operative due to the distance between the last step on the stairway and the beach due to the removal of sand (Figure 9). This forces users to look for alternative access along this part of the beach.

To measure the importance of this interaction, we present the indicator of beach wobbling, IBW, which is given by the ratio between the beach length, with a width larger or equal to the optimum value (from a recreational standpoint; here assumed to be 30 m) and the total length:

$$IBW = L\ (W \geq W_{OP})\ /\ L_{total}$$

The lower the value of the indicator, the less suited the beach morphology is to intensive recreational exploitation. By estimating this indicator for the two beach configurations shown in Figure 9, we obtain a value of 1 for the 2000 configuration (i.e. the entire beach length was optimal for use and exploitation), whereas in 2004 the value decreased to 0.55 (i.e. 45 % of the beach was narrower than the optimum value). It must be taken into consideration that, in both cases, the mean beach width was almost the same, about 50 m.

In this specific case, the extreme variation in beach width is caused by the cumulative effect of a large number of easterly storms that occurred during the November 2003 to May 2004 period. The absence of southerly storms, which are typical of the February-April period, prevented the natural redistribution of the sand from the western end to the eastern end. As a result of this, the municipal authority planned to artificially reorient the shoreline by transporting sand from the western end to the eastern end. This was done at the beginning of June, because the probability of a late storm was very low at that time and also because it was the start of the bathing season. In this way, the local manager, i.e. the municipal authority, organises the beach as effectively as possible for the summer.

The proposed indicator can be used to track year-to-year variations in the beach configuration to modify/adapt beach exploitation strategies and associated services. If combined with a shoreline numerical model (see review in Hanson et al., 2003), the manager will be able to get a measure of how far the beach will be out of the optimum configuration for a given wave climate. This will permit the manager to anticipate exploitation problems due to shoreline reorientations for different wave scenarios (waves arriving from different directions) and to be ready to take action.

Storm-induced Changes

Finally, as mentioned above, during typical climatic years there will be a time-lag between the period of storm waves and the beach's recreational season (Figure 4). However, there will be some situations in which storms may affect the full exploitation of the beach.

This interaction will occur when storm impacts are reflected in the configuration of the beach during or just before the tourist season. This is the time when beach services have to be planned and prepared. In an ideal world, the manager of a Mediterranean beach needs to know the optimum beach configuration for recreational purposes in April or May to enable services to be planned adequately for the season to come.

However, a change in the typical wave climate may lead to a shift or delay in arriving at the beach configuration that is required for the summer. This will mainly occur when the storm season is longer than usual and natural recovery processes cannot rebuild the optimum beach. This situation occurred on the Catalan coast in the summers of 2002 and 2004, when the previous storm seasons in the two periods were much longer than usual, with frequent and very intense storms from November to May. All this prevented the natural recovery of beaches and many beaches along the Catalan coast were sediment-starved just before the start of the bathing season. As an example, several beaches in the Catalan coast such as Bassa Rodona (Sitges, Barcelona) presented at the beginning of the 2004 bathing season no subaerial part to support its normal use and exploitation. This beach is laterally limited by two groins and, although its width has gradually been decreasing, the largest retreat was detected in the aforementioned "extreme" storm season of winter 2001-2002. The cumulative effect of the other "extreme" storm season of winter 2003-2004 on a beach that was already sediment-starved (the carrying capacity of the beach decreased by 50% after that season, according to a pers. comm. by the Associació de platges -Beach Association-) meant that the beach could not be exploited (sun bed and parasol hire services) because, although it was officially permitted and there were plans to do so, there was no beach to be exploited.

This effect can be included in the interaction model between beach width and carrying capacity introduced above (Figure 5), by superimposing it on the long-term beach evolution. Thus, if one year is characterised by an extremely stormy season (due to more intense or more frequent storms), the corresponding width will decrease sharply below the expected value (Figure 10). This decrease will be transferred directly to the carrying capacity of the beach during the corresponding bathing season of that year. The recovery of "normal conditions" will depend on the efficiency of the accretion processes once the “normal” climate is established. In any case, it must be taken into consideration that the velocity and intensity of erosion processes largely exceeds accretive ones (Komar, 1998) and as a result the presentation of successive events of this type can have a cumulative effect and make efficient beach recovery difficult.

In such cases the beach does not have a large enough surface area to support the recreational services planned. Consequently, managers have to take measures to accelerate the recovery process. The emergency nourishment of a beach is usually undertaken in areas in which the beach is not in ideal conditions at the start of the bathing season, or sometimes when there is no beach at all. It should be borne in mind that these nourishment operations are not designed to compensate for the erosion of the beach. Moreover, in those areas in which the beach is essential for the local economy and when natural recovery processes have not been able to correct the damage in time, the aim of these replenishment operations is to create a beach of a minimum acceptable quality.

Discussion and Conclusions

The potential influence of shoreline dynamics on beach use and the exploitation of beaches for recreational purposes was analysed for Mediterranean-type beaches. This was done in terms of the beach carrying capacity, which for intensively used beaches such as those considered in this work is mainly influenced by the subaerial surface that is available. This is formalised by means of a conceptual model of interaction between beach width and human use, which can be used by the manager to anticipate the appearance of beach exploitation problems due to a decrease in beach carrying capacity.

The model requires two time-dependent input variables, shoreline rates of displacement and number of users. Since both two input variables have to be introduced in the analysis as time series during the projection period, the reliability of carrying capacity estimations will depend on the associated uncertainty. This makes that to properly manage the beach, it should be necessary to (quantitatively) know how the system is functioning at present and how will function in the near future. Although this is an obvious statement, present situation in most of the Mediterranean coasts seem to illustrate that this is not the case because no anticipation to actual problems was detected.

This could be easily solved by including an assessment of the beach system performance due to coastal dynamics and human use in the formulation of any beach management strategy (see e.g. Micaleff and Williams 2002). Beach width evolution can be estimated by analysing shoreline data time series (e.g. Dolan et al., 1991) for no change in boundary conditions (such as the construction of any coastal structure) or by using proper coastal numerical models (see review in Hanson et al., 2003). The time evolution of the number of beach visitors can be estimated e.g. by using destination lifecycle models (Butler, 1980; Hovinen, 2002) or ad-hoc models for the specific site (e.g. Aguiló et al., 2005). All of this implies that beach data collection to calculate these projections must be included in any management plan. In addition to this, the implementation of a monitoring programme will also serve to check the performance of the management plan and to adapt it to observed

The proposed interaction model serves to define management strategies for beaches exploitation. Thus, for beaches subjected to an intensive recreational use, it can be used to identify beach sectors where corrective actions have to be taken to maintain an optimum beach width. Moreover it can be also helpful to decide the moment to take action and to design the magnitude of the required action. In the case of beach management in new tourist destinations, the model would help the manager to predict the appearance of conflicts in beach exploitation for different scenarios of number of users. This will help to take decisions in estimating the beach carrying capacity by defining the beach user profile.

Since erosion is becoming a dominant process in world coastlines (e.g. according to the Eurosion Project conclusions, all the European coastal states are to some extent affected by coastal erosion, Eurosion 2004), this kind of interaction models will be a common tool to properly define beach management strategies for recreational purposes.

At present, most of the actions to afford actual problems of decreasing beach carrying capacity are orientated to classic coastal engineering measures such as beach nourishment being the maintenance/increase of the beach width the main operational objective. This strategy is typical of mature tourist destinations based on the sun and sand mass tourism model. However, actual policies are being oriented towards a different vision by introducing alternative criteria. Thus, for instance, the Council of Europe (2003) proposed to incorporate the interaction between coastal erosion and tourism into local and national tourism development strategies and promoting quality-oriented tourism and resource management among others aspects.

The examples of interaction between coastline dynamics and recreational use presented in this paper, although limited to a geographical area, can be considered as representative of many of world coasts. Thus, the increase in human use of beaches and, the more or less generalized erosion of our coasts, makes this kind of potential problems one of the first aspects to be faced by beach managers to estimate beach carrying capacity for tourist destinations.

Finally, although it is evident that long-term erosion is the main threat to beach exploitation for recreational purposes, other theoretical reversible processes such as bay shoreline fluctuations and storm-induced erosion can also affect the proper beach exploitation.

In consequence, service planning has also to consider the magnitude and frequency of such processes.

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FIGURE LEGENDS

Figure 1. Area of study.

Figure 2. Across-shore zonation of a beach profile from a recreational perspective.

Figure 3. Distribution of beach users across a wide beach in Costa Brava -sa Riera beach, Girona-.

Figure 4. Monthly averaged significant wave height in the Catalan coast and number of non-Spanish visitors to Catalonia in 2001.

Figure 5. Relationship between beach width evolution in long-term eroding beaches and carrying capacity measured in terms of available and used surface per user.

Figure 6. Vertical aerial photograph of s'Abanell beach taken in summer 2000. Insets illustrate the different level of occupancy along the beach (Institut Cartogràfic de Catalunya).

Figure 7. Long-term shoreline rate of displacement along the s'Abanell beach (Blanes, Girona) during recent decades.

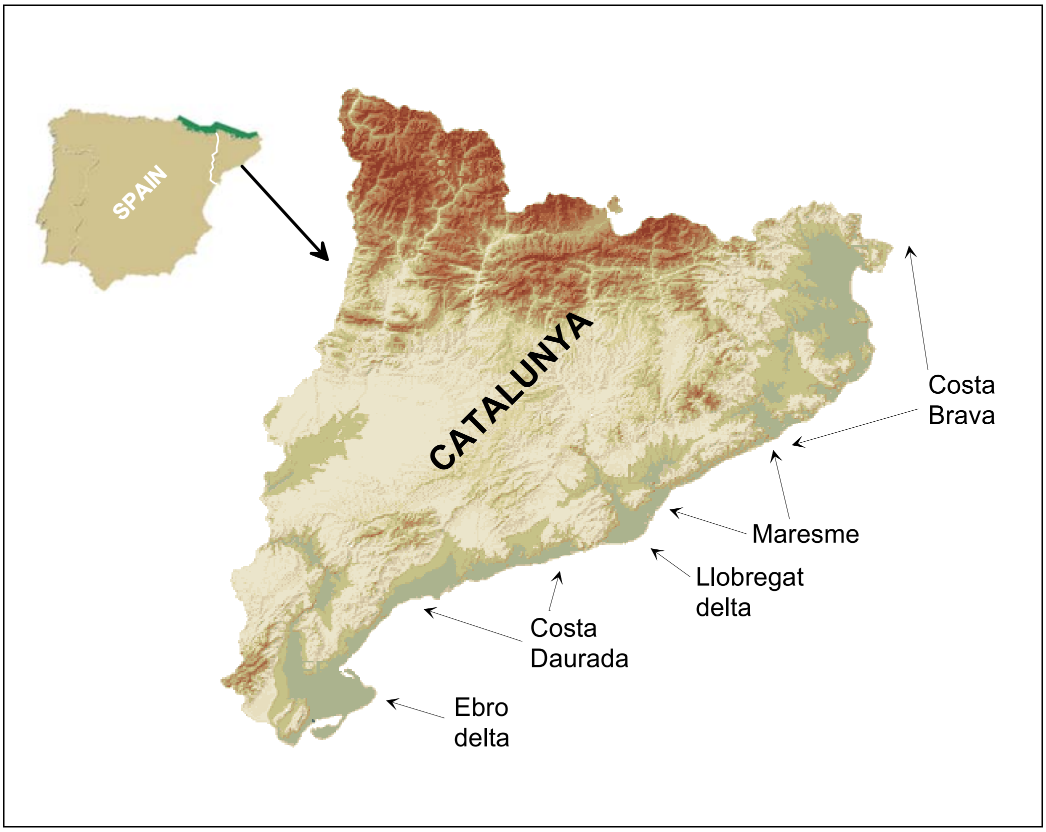
Figure 8. Evolution of the carrying capacity of the s'Abanell beach –measured in terms of available beach surface per user- due to long-term shoreline changes.

Figure 9. Extreme reorientation of the shoreline of Lloret de Mar beach towards the south in summer 2004 – line - (background photo corresponds to the beach configuration in summer 2000, Institut Cartogràfic de Catalunya) (*top*) and a detail of beach status at the northern end (*bottom*). The circle indicates the site of the photo.

Figure 10. Additional storm-induced influence on the carrying capacity of long-term eroding beaches measured in terms of available and used surface per user.

Table 1. Typical dimensions of beach zones for recreational purposes in Spain.

zones	wide beaches (> 50 m)	narrow beaches (< 50 m)
active	15	10
resting	25	20
safe	10	10
service	variable	rest



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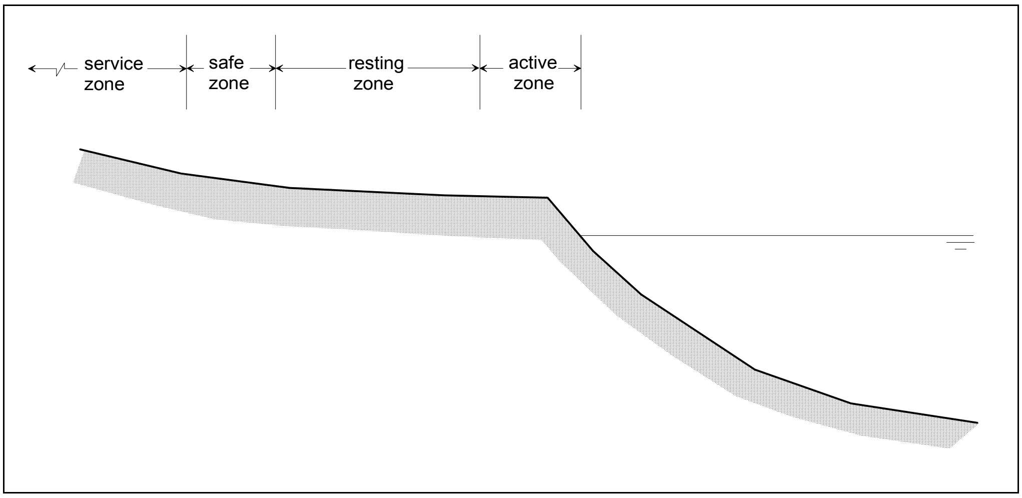

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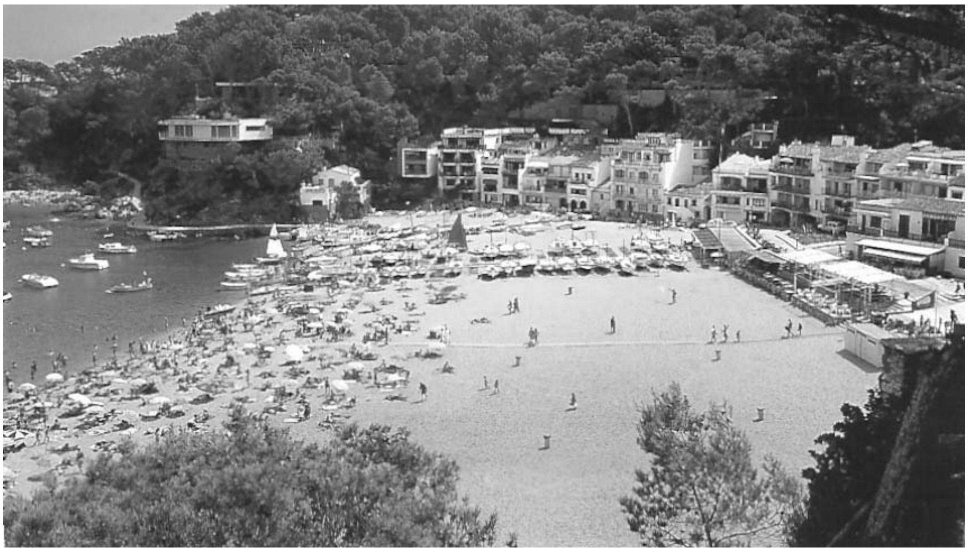

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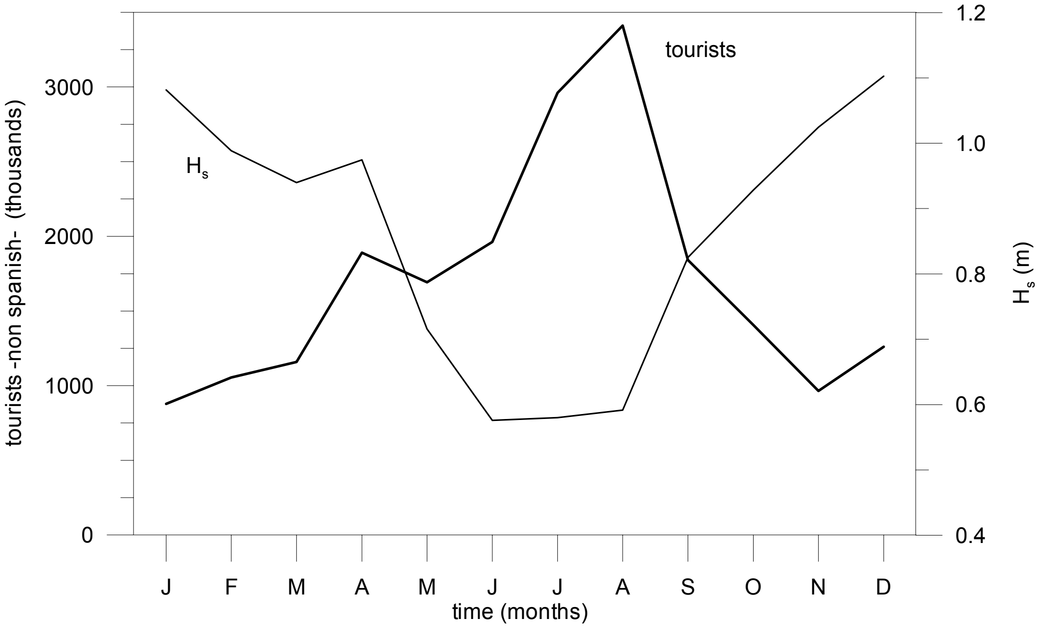

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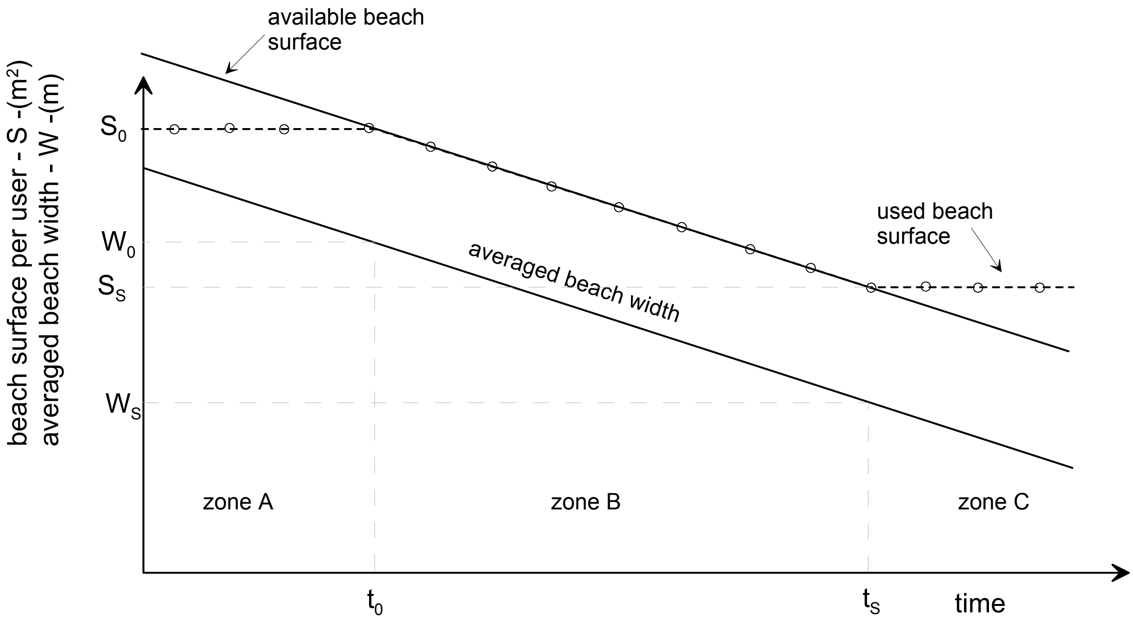

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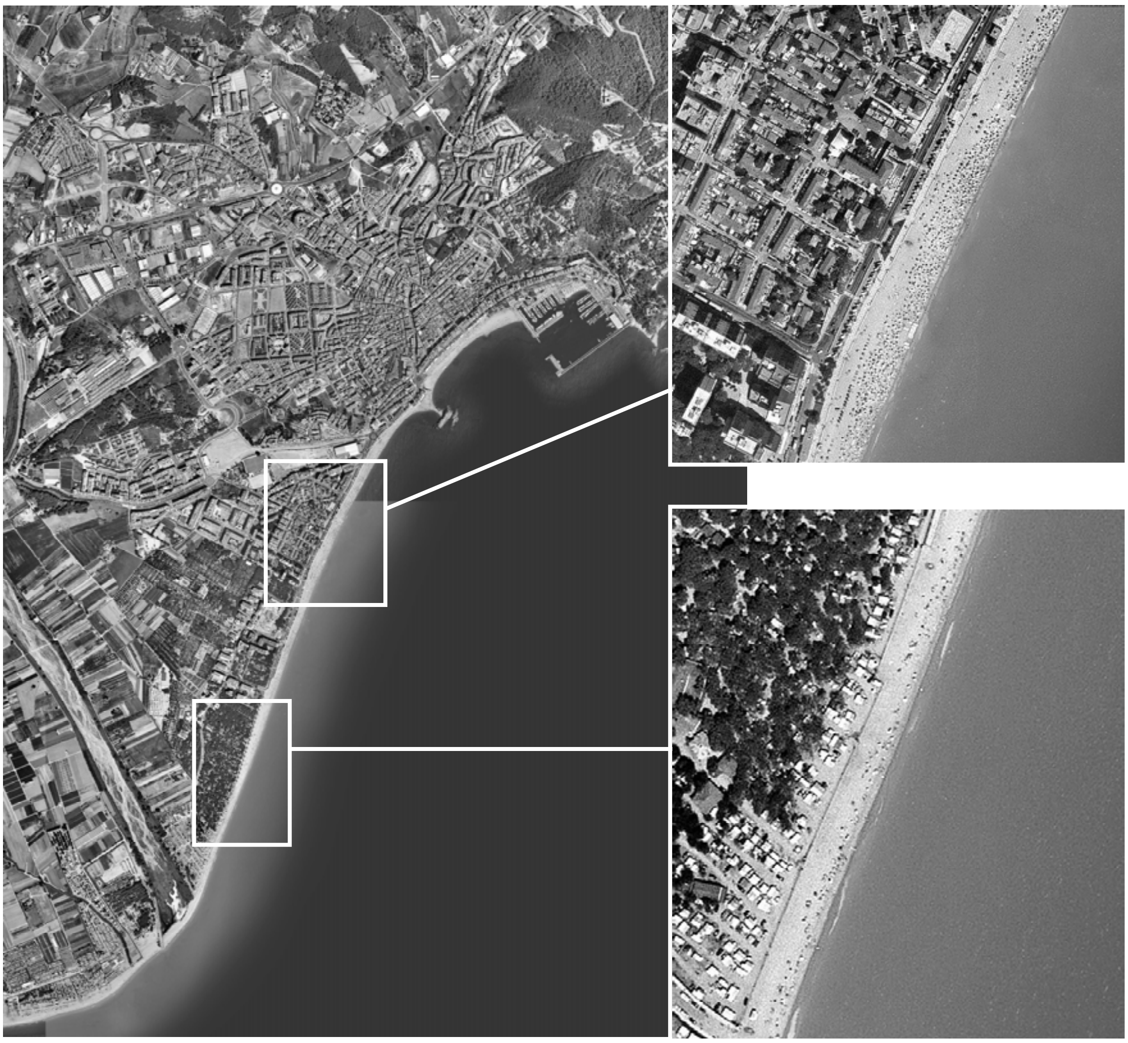

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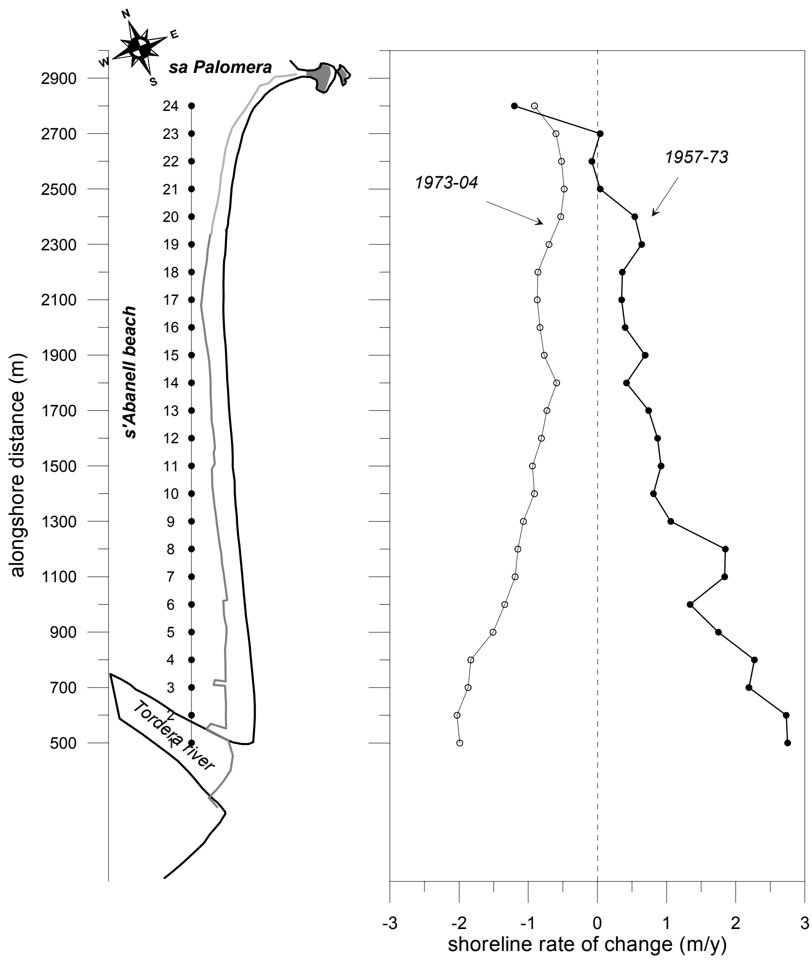

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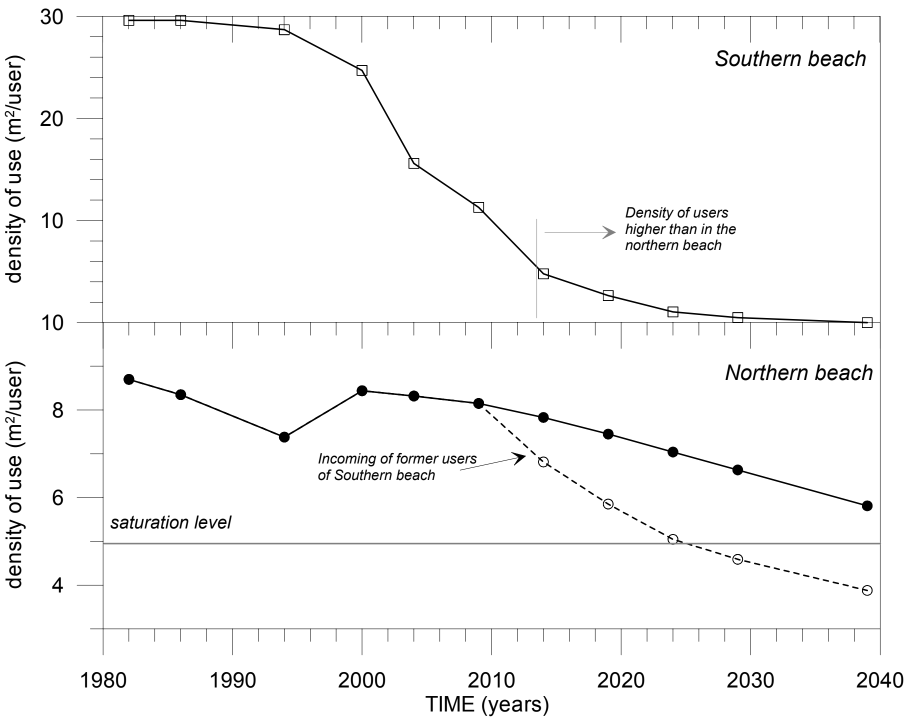

Figure 8

Figure 9 Top

Figure 9 Bottom

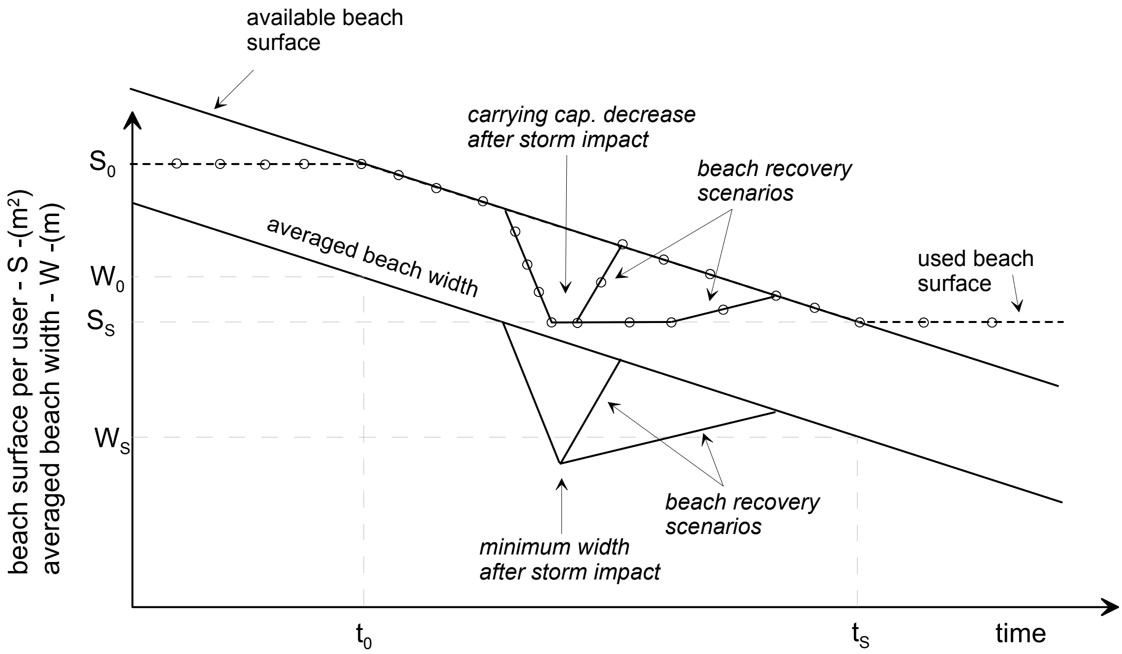
available beach surface
carrying cap. decrease after storm impact
beach recovery scenarios
used beach surface
averaged beach width
beach recovery scenarios
minimum width after storm impact
beach surface per user - S -(m²)
averaged beach width - W -(m)
S0
W0
SS
WS
t0
tS
time

Figure 10