Managing bathers' capacity in overcrowded beaches: a case on the Spanish North Atlantic coast

Imanol Basterretxea-Iribar , Iranzu Sotés , María de Las Mercedes Maruri

Abstract

Tourism development in small beaches leads to overcrowding and, consequently, tends to increase the hazards for bathers. The techniques to manage the bathers' capacity include the knowledge of the area where the bathers may enjoy themselves far away from beaches' dangers. The marine environment, the demography pressure and the popularity of sport activities such as surf may affect the safety in the bath zone. Moreover, the area of this bath zone may change due to beach morphodynamics. Beaches in Biscay (Spanish North Atlantic coast) are small as a consequence of a rocky coastline and, consequently, the overcrowding is a real danger. This paper is a part of a research promoted by the Biscay Regional Council Office that provides a superficial beach model to manage beach occupancy. The output data refer to a safe bath zone and the maximum bathers permitted.

Keywords

Beach overcrowding; safe bath zone; bathers' capacity; spatial distribution

Introduction

Beach is defined as an area of sediments, usually sand or smooth stones, deposited beside the sea or a lake which includes the backshore, the intertidal area and also the surrounding waters or bath zone. Usually the use of the beach is public and it is the call for people to enjoy and cool themselves off. However, the area of a public beach has to be wide enough to hold users in a sustainable and safely way. Studies on the consequences of the overexploitation to the beach environment and survival are numerous. They are mainly related to the influence of physico-ecological and socio-cultural factors in the beach carrying capacity (Zacarias et al., 2011). Models and indexes to evaluate the beach management and the economical and environment impact are also abundant (Lucrezi et al., 2016; Navarro et al., 2012; Sarda et al., 2015; Lozoya et al., 2014; Mustain et al., 2015). Even researches have been carried out on how the beach overcrowding is perceived by the tourists (Navarro et al. 2013) and how the carrying capacity tools have to be used, not only to limit, but to improve tourist visitation (Santos, 2015). However, this research is related to beach safety management and, in particular, is focused to calculate the area of a safe bath zone (SBZ) for distribution of bathers in overcrowded beaches. The application of this method is not only directed to avoiding drowning, the whole figure of which sum up 487 cases during 2016 and 481 in 2017 in the beaches, rivers, lakes and swimming pools of Spain (RFESS, 2018); but also to manage a tourism problem which is the safely distribution of bathers within the beach water.

Legal background in Spain

The public zone of a beach depends on the internal law of each state. In Spain this public space may be formed by three different areas: the inland area, the beach and the offshore waters. The inland area is that which extends along the coast between the lowest astronomical water mark and the boundary line reached by the waves during the known major storms. The beach is defined as deposit of sand, pebbles and/or loose stones, including scarps, berms and dunes and it may be extended beyond the inland area up to the limit necessary to ensure the sustainability and defence of the coast according to article 3 of the Spanish Shore Act (Ley de Costas, 1988). The offshore waters are composed by the internal waters and territorial sea (UN, 2018).

The bath zone is an area of the offshore waters limited by a specific distance from the shoreline, except in the case that this zone is marked with buoys. In Spain, this distance is 200 meters for the beaches and 50 meters for the rest of the coast according to the Spanish Shoreline Regulation 2014 (Reglamento general de Costas, 2014). Navigation of power-driven and sailing vessels is not permitted inside the bath zone except in the channels marked for beaching purposes. However, the use of surf tables and rowing boats as kayaks is permitted in the bath zone, what means an additional hazard for the bathers. To reduce this risk, marks for limiting surf areas on the beach tend to be used and regulated. For instance, the Harbour Master of Bilbao port provided general rules under the Resolution of March 9th 2012 for navigation and maritime safety focusing on the bath zone. Currently this regulation has been abolished waiting apparently for a new regulation coming from the Basque Country Government. Nevertheless, the effectiveness of these regulations have to be tested since the beachgoers should notice the warning signs at beaches (Matthews et al., 2014)

Bath zone safety

Safety in beach waters depends mainly on the sea conditions, but there are others parameters which also influence on the task of the lifeguards. One of them is the extension and overcrowding of the beach that may affect in a double way (Silva-Cavalcanti et al., 2018). In case the beach is wide and long, the vigilance should be extended along to all the shoreline and, consequently, the necessary infrastructures and human resources would be exaggerated and impracticable. The solution to those cases is to set bounds to the bath zone as it occurs in the South Atlantic beaches of France. On the contrary, if the beach is small and overcrowding, there will not be problems in the vigilance limits but beachgoers' harmony may be affected in the bath zone, even more when the users who take a dip have to share this area with sport activities as surf, SUP, kayak, etcetera. This is a real problem in the Basque Country coast and especially in Biscay province where the beaches cannot support demographic pressure because they are embedded in small coves. The problem is not the overcrowding but the size of the beach. Therefore, the Biscay example does not seem similar to the cases of urban long beaches located in densely populated towns (Breton et al., 1996). Moreover, the high tidal range in this area is another parameter which causes variations in the beach morphology and dimensions affecting, consequently, to the safety in the bath zone. In consequence, the rip currents may change their direction and/or intensity throughout daily hours and the rocks may be emerged and submerged in a few hours limiting the usable area. It may be concluded that the bath zone according to the legal terms is not always a safe area and it is necessary to delimit a SBZ inside the legal bath zone.

On the other hand, the excess of bathers will depend on the dimensions of the beach and the beachgoers' demand. Obviously, safety of the beach is mainly affected by the sea conditions in the first instance but the overcrowding may also have influence on the task of lifeguards. The aim of this paper is to obtain the area of a SBZ by means a superficial beach model.

The spatial distribution of bathers within these small areas, together with the recommendations suggested by some organisations, may reduce the accidents and drownings (WHO, 2014). In that sense, the ability to swim and recognise the meteorological conditions and hazards is relevant (WHO, 2008).

Methods and data

2.1 Study area

The research project has been carried out in the more relevant beaches of Biscay, however only three beach zones are studied in this paper to avoid information overload. These zones meet all the requirements and variables used in the methodology.

2.1.1 Biscay beaches

The study area has focused in the sandy beaches of Biscay coast belonging to the Basque Country. This area contains nine main beaches and more than ten secondary beaches. Moreover, there are other three beaches under the control of the port of Bilbao. The consideration of secondary beach is because of its reduced area and/or the difficulties in the access. In this sense there are some beaches below the cliffs where the only way to entry is through a dangerous path. Table 1 provides the length of the shoreline for main beaches under three different tide levels (high, medium and low water). As can be seen, all beaches except one are less than one kilometre long.

Table 1

BEACH	TIDE		
	High water	Medium water	Low water
Playa de La Arena	837 m.	814 m.	790 m.
Playa de Barinatxe	563 m.	596 m.	628 m.
Playa de Arriatera - Atxabiribil	829 m.	813 m.	796 m.
Playa de Plentzia	343 m.	324 m.	312 m.
Playa de Gorliz	867 m.	794 m.	720 m.
Playa de Bakio	925m.	868 m.	810 m.
Playa de Laga	543 m.	629 m.	714 m.
Playa de Karraspio	399 m.	462 m.	524 m.
Playa de Laida	222 m.	626 m.	1.270 m.

2.1.2 Demography

In Biscay beachgoers tend to come from the local regions near the coast, including Bilbao and its surrounding towns where the population density is larger than other areas. Most of Biscay workers are on leave during August. Some of them go abroad on holidays but others stay at towns near the coast. On the other hand, beachgoers' density is higher in the afternoon (evening) since the daily work time finishes at around 15:00 during the summer. Table 2 shows the number of citizens in Biscay with respect to the local regions and age in 2016 (Eustat, 2017b). With regard to the tourism income, visitors staying overnight in the Biscay coast during 2016 summer sum up 26,559 in June; 45,709 in August and 30,463 in September (Eustat, 2017a). In respect of the study area where the research has been carried out, the study beaches are located in the towns of Plentzia and Gorliz where the regular population in 2017 was respectively 4,304 and 5,669. However, these figures tend to quadruple during the summer due to a tourism pressure. Most beachgoers (74%) in Biscay enjoy doing three main leisure activities: sunbathing, wading and bathing (Sotes et al., 2018). On the other hand, the popularity of surfing as leisure activity in Basque Country has risen during the last years as occurred in other countries as Australia (Lanagan, 2002). Benefits of this increase are large taking into account the number of rescues conducted by surfers; however, the overcrowding of beaches in summer does not permit the surf practice under safety conditions. The number of surf schools and camps in Biscay summed up 46 in 2016 and this figure seems to be constant presently due to the current restriction policy in giving licenses to new surf schools. In particular, ten schools gave short courses in the beaches under study some of them being itinerant.

Table 2

Local regions	Total	0-19	20-64	> 65	Coast proximity
Bilbao	342,481	55,213	206,416	80,852	Coastal region
Bilbao surroundings	857,044	144,321	518,933	193,790	Coastal region
Duranguesado	98,229	18,876	59,998	19,355	Inland region
Encartaciones	31,984	5,567	19,632	6,785	Inland region
Gernika-Bermeo	45,688	8,190	27,155	10,343	Coastal region
Foothills of Gorbea	8,777	1,868	5,447	1,462	Inland region
Markina-Ondarroa	26,014	4,533	15,516	5,965	Coastal region
Plentzia-Mungia	56,207	11,989	35,218	9,000	Coastal region
Arratia-Nervión	23,686	4,597	14,401	4,688	Inland region

2.1.3 Oceanic-meteorological conditions

Meteorology in the Basque coast is mild and changeable what means that beach agglomerations takes place usually in specific dates when the temperature is high and the sky is clear. Prevailing wind tends to come from northeast and intensity is mainly soft.

With respect to sea conditions, swell is usually coming from northwest and it is mainly generated by the storms in the zone of Atlantic Ocean close to Ireland. Seawater temperature is around 20ºC and suitable for the bath in summer. Table 3 shows the significant height and maximum height during 2016 summer observed in Bilbao oceanographic buoy (Puertos del Estado, 2017).

Table 3

	Significant height	Maximum height
June 2016	1,4	2,3
July 2016	1,3	2,2
August 2016	1,6	2,9
September 2016	2,6	4,6

2.1.4 Study beaches

This research aims to obtain a beach model for calculating the SBZ of beaches of Plentzia and Gorliz. In fact it is only one semicircular beach located inside a little bay under the administrative control of two councils: Plentzia and Gorliz. They are two summer holiday towns which are linked to Bilbao and its surroundings by underground. The whole beach may be divided in four zones depending on how the swell and currents are affecting them. Hence, Plentzia beach has been divided into two areas: zone A and B; and Gorliz is also divided into other two parts: zone C and D. Zone A is near the mouth of tidal river under the effect of a special current and prevailing northwest swell where a bar is formed permitting surfing activities all year long. Zones B and C are also under the effect of the refractive waves coming from predominant swell whereas zone D is protected by a small dock which makes its waters calm. The study aims to provide three different beach models for A, B and C zones which are shown in figure 1. Given that these two beaches are semicircular; the radius of each zone for high and low waters is also shown. There are also two artificial obstructions which affect the zone B and C in high waters: the building of the Plentzia Marine Station (PMS) and Gorliz promenade.

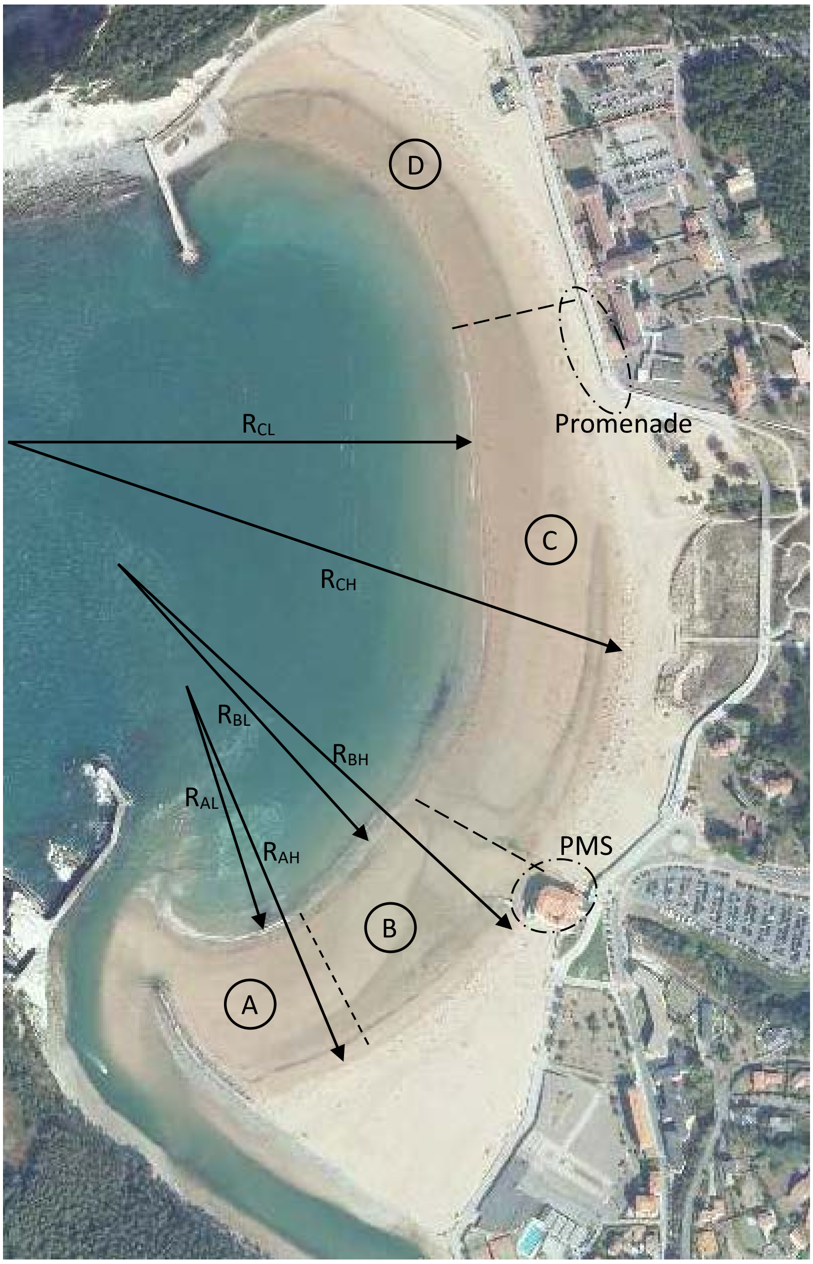

Figure 1

Currents and bar location are shown in figure 2. The picture was taken at the beginning of August 2016 when the bar is moving to the high water shoreline. The research was carried out at the end of August and, consequently, the troughs permitting water drain are not so large. In the same way, figure 2 provides a general distribution of the rip currents, the intensity and extension of which may change due to the force of waves and tide.

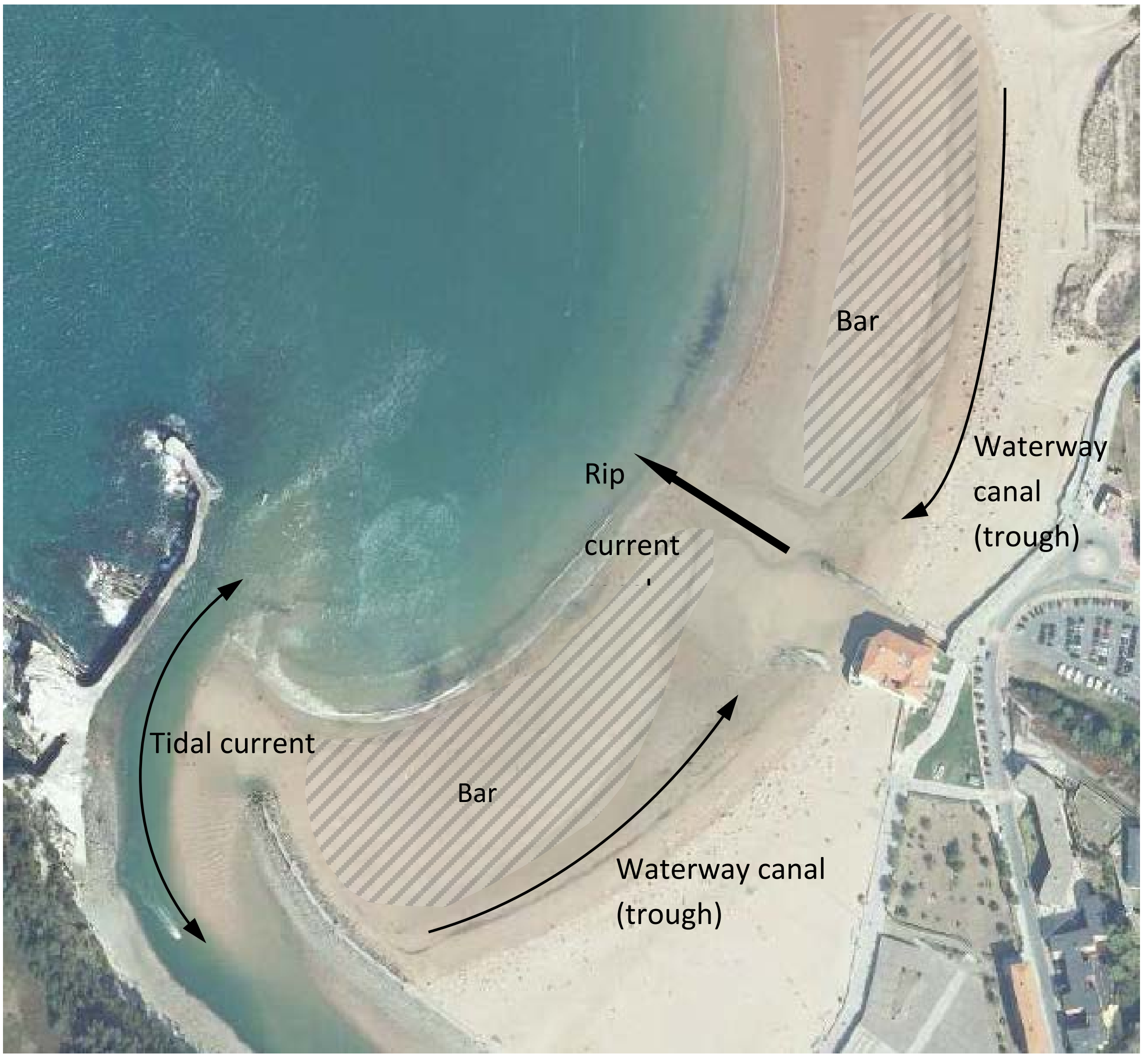

Figure 2

2.2 Superficial beach model

Safety in the bath zone depends mainly on the waves force and the slope of the beach. Obviously, the SBZ is reduced when the slope is high because the bathers go out of their depth near the shoreline. Bathymetry may be carried out to know bottom shape and slope; however this process is very laborious and requires a specialized boat. Moreover, beach bottom shape is changing continuously and the results would be useful only for a short time. The present research calculates SBZ based on the distance of the shoreline to the breaking waves (DSBW). It is necessary to collect this data for a short time (around one fortnight) under different tide as well as the wave height conditions. A longer extension of this interval of time may bring the beach to change significantly this bottom shape and, as a consequence, calculations would not be right. The superficial beach model has to be fed by the beach mean particulars and the variables of tide, wave height and currents in order to obtain the SBZ and the maximum number of bathers within the water (MAXBATHERS) according to the diagram of figure 3.

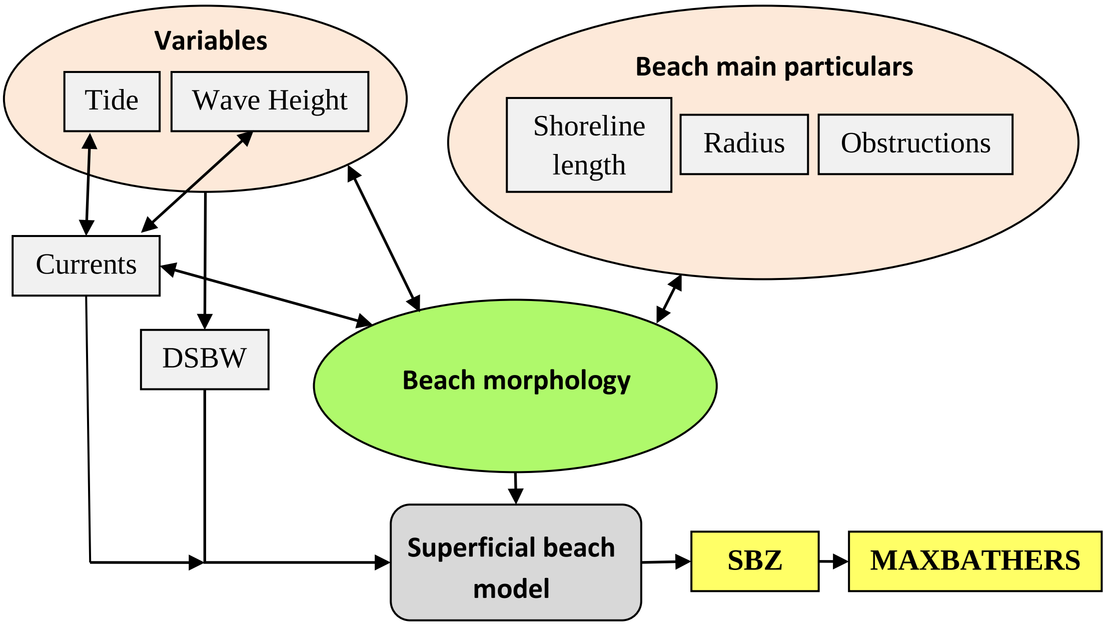

Figure 3

2.2.1 Variables

The main variables affecting the bath zone are the tide and the wave height. There are other effects as the currents or the beach bottom changes which depend on these main variables.

Tide

Obviously, the tidal influence on the beach will depend on its range. In the case of Mediterranean Sea, the difference between consecutive low and high tides is very small -only a few centimetres- and, consequently, there are not changes in the beach due to the tide. On the contrary, this difference may reach more than four meters in the Basque Country and, consequently, all the data included in the graphics and tables of this paper are provided for ±2 meters in respect of the mean sea level. Moreover, the tidal range may vary from two to four meters depending on neaps or springs. Mean level, however, is constant due to the limited influence of the storm surges (Shevchenko, 2017). That seems to be in accordance with the narrowness of the continental shelf. Nevertheless, storms during 2014 winter extended for a long time which generated an unusual rise in mean-sea level, changing the morphology of Biscay beaches, which seems to be in accordance with studies carried out in North Carolina (Munroe and Curtis, 2017).

The tide has a direct influence on the size of the area for bathers since the water is moving and, in this way, it is occupying different spaces. However, there is also an indirect influence of the tide in the bath zone due to the changes in the direction and rate of the rip currents, the appearance of rocks and obstructions, the alteration of beach bottom and other factors. According to the observation carried out in the study beaches, this indirect influence may be even higher than the direct one.

Wave height

Wave height is a variable which is related to the sea energy or the force of the wave. If the height is increasing, the energy is higher and, consequently, the wave breaks more violent in the beach. Other parameter, related in many cases with surf-zone injuries, is the beach slope which might also have influence on the force of the breaking waves (Muller, 2018). In particular, the bottom slope affects the way the wave energy is absorbed. The conclusion is clear: the bath within the beach waters becomes more dangerous in case the wave height is high and the wave breaks violently.

Moreover, the waves affect directly the rate of the rip currents which have a direct influence on the beach safety. The beach bottom shape may also change drastically during the storms when high waves reach the coastline. Nevertheless, there are beaches where the rip-currents may reach 0.5 m/s in response to low-energy incident waves (Leatherman, 2017).

Data related to the wave height were obtained from Bilbao oceanographic buoy located a few miles from the beaches under study. In particular, significant wave height data were collected. Taking into account that this wave height corresponds to the mean height of the highest third of waves, the observation in the beach focused only on the highest waves group.

2.2.2 Parameters

In addition to the variables cited before, there are some parameters related to the beach shape, slope and currents and, on the other hand, to the bathers' behaviour which have influence on the extension of bath zone. These parameters will depend on the tide and wave height. Some of them must be obtained through a correct inspection and observation and, of course, under a correct method of validation.

Data related to the parameters are collected under different conditions of tide and wave height creating a matrix for each parameter. Data observed has been processed through the application of a cubic spline approximation to obtain intermediate data which were not collected. Lowest square method was also used to screen data of some parameters. In some cases, the data observed have been validated by other methods of observation.

The parameters selected are as follows:

Shoreline (SL)

It is the length of the shoreline of the beach. It depends only on the tide and the wave height has not got influence. Taking into account that the Biscay beaches are embedded in the rocky coast, this parameter does not tend to change. Table 1 provides the shoreline length for all main Biscay beaches under low, medium and high waters' levels. On the other hand, same data are provided for the three zones under the study in table 2.

Table 2. Shoreline lenght

BEACH ZONE	TIDE		
	High water	Medium water	Low water
Plentzia A	110 m.	140 m.	160 m.
Plentzia B	230 m.	180 m.	150 m.
Gorliz C	580 m.	530 m.	480 m.

Radius (R)

Bearing in mind that the beaches of Plentzia and Gorliz are semicircular, a different radius is provided for each zone under the research. This parameter is relevant since the bath zone is reduced the smaller the radius. This parameter is shown in table 3.

Table 3. Radius

BEACH ZONE	TIDE	
	High water	Low water
Plentzia A	360 m.	220 m.
Plentzia B	520 m.	400 m.
Gorliz C	540 m.	420 m.

Obstructions (O)

In many occasions the beach is not usable because of the appearance of rocks on the bottom or due to artificial installations or constructions. As can be seen in figure 1, a promenade and a building are affecting the beaches in high waters. That means the shoreline length is reduced in 40 and 80 meters in zone C and B respectively for a few hours during high waters. This interval may be longer than three hours during springs and less than one hour during neaps. Moreover, a single area may be affected at the same time by the currents and obstructions. This fact seems to be usual taken into account that the very obstructions tend to generate rip currents. Therefore, the real shoreline due to obstructions is deducted by the currents affecting in the same area obtaining the resultant shoreline. Table 4 shows the resultant and real meters of shoreline under the influence of obstructions.

Table 4. Obstructions

		Plentzia Zone B			Plentzia Zone B			Gorliz Zone C	
Wave Height		Real	Resultant		Real	Resultant		Real	Resultant
0.5		0	0		40	40		80	80
0.9		0	0		40	40		80	80
1.3		0	0		40	30		80	80
1.7		0	0		40	25		80	80
2.5		0	0		40	20		80	70

Distance from shoreline to breaking waves (DSBW)

Depth is an important parameter to measure safety for bathers. Basically, the bath zone stops being safe when the bathers leave to bottom. Taking into account that the wave breaks when the depth is around 1.3 times its height, the line of breaking waves is a good boundary for limiting the SBZ. The area between the shoreline and the line of breaking waves is safer than the sea area beyond this line. Therefore, the distance from shoreline to breaking waves is one of the most relevant parameter to obtain the bath zone. Moreover, this parameter is not fixed and is changeable according to the wave height. It will be short for small waves and larger for higher waves.

Raw data related to DSBW was collected by the lifeguards by means of the observation of the highest waves group reaching the beach. As mentioned before, the data of wave height used in the research correspond to this type of waves.

A validation process was conducted and performed to confirm the data obtained by lifeguards. In order to carry out this process, wet beach was marked off with various milestones separated every 20 meters from the shoreline during the low waters and a picture was taken from a fixed photograph camera. Then, various straight lines were traced connecting the milestones. These lines, perpendicular to the shoreline, were used overlapped on other pictures taken by the same fixed camera when the tide was high. In this way, the DSBW was calculated and compared to the raw data obtained by lifeguards. Time-exposure photography techniques were used to obtain the data related only to the highest waves. Therefore, various pictures taken each five seconds apart during a period of 20 minutes were integrated to measure the distance between the shoreline and the furthest breaking wave foam.

DSBW data collected by the lifeguards during the end of August 2016 are shown in table 5 after screening. In first instance, the collected data have been screened by the elimination of non-correlated data. Next, the resulted data have been processed by cubic spline method to obtain full data. In case there was a disparity in the collected data, a least squares method may also be used for screening.

Tabla 5. DSBW collected

		Plentzia A					Plentzia B					Gorliz C				
	W.Height→	**0.5**	**0.9**	**1.3**	**1.7**	**2.5**	**0.5**	**0.9**	**1.3**	**1.7**	**2.5**	**0.5**	**0.9**	**1.3**	**1.7**	**2.5**
Tide Range	**2**	5	10	30	50	80	5	10	30	50	80	5	15	30	60	80
	1.75			35		85			35		70			45		80
	1.5	10	20	40		90	10	20	40		90	5	25	50		90
	1.25				60					60					70	~~80~~
	1	10	25	50		100	10	25	50		100	10	30	60		100
	.75	~~20~~				100					100					100
	.5	10	30				10	25				10	30			
	.25			50					50					60		
	0					90					90					90
	-0.25	10	30	50		90	15	30	50		90	10	30	55		90
	-0.5				60			~~45~~		60					70	
	-0.75			50		~~120~~			50					50		~~80~~
	-1					100					100					90
	-1.25	15	30	50	60	100	20	40	50	50	100	15	35	50	60	90
	-1.5	~~20~~								~~55~~					~~55~~	
	-1.75	15	25		60	~~110~~	20	40		50		15	35		60	
	-2	10	20	40	55	90	20	30	40	50	100	10	30	40	50	90

In figures 4, 5 and 6 full DSBW data are shown for the three areas studied after processing.

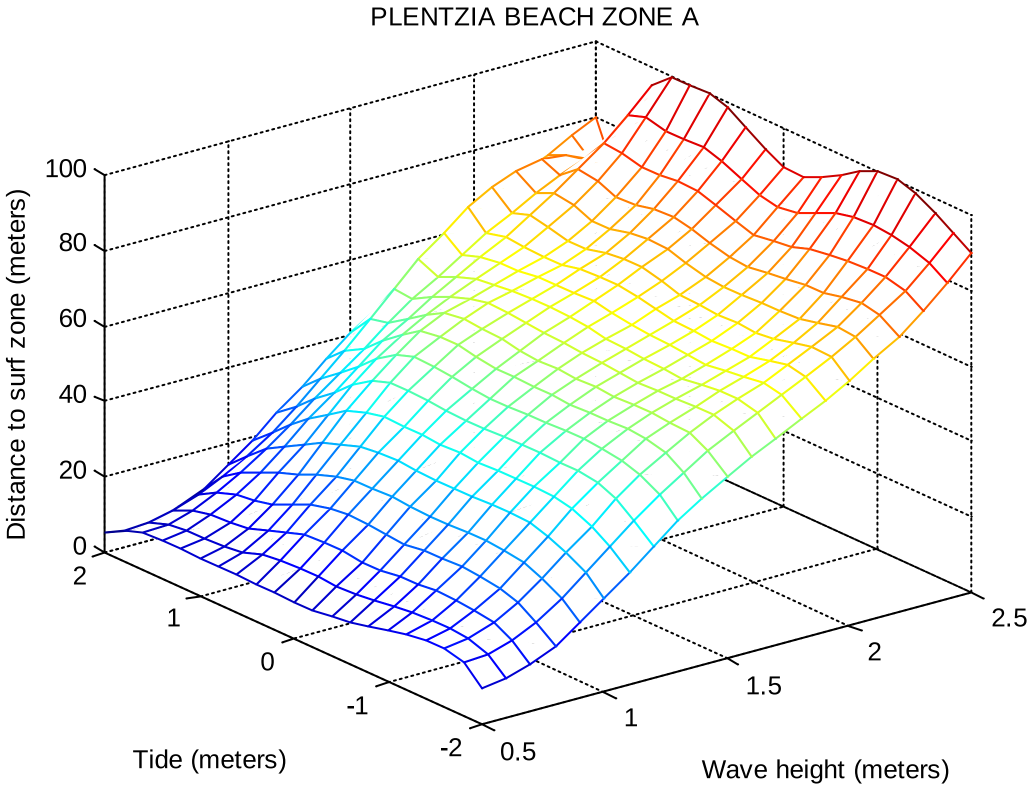

Figure 4

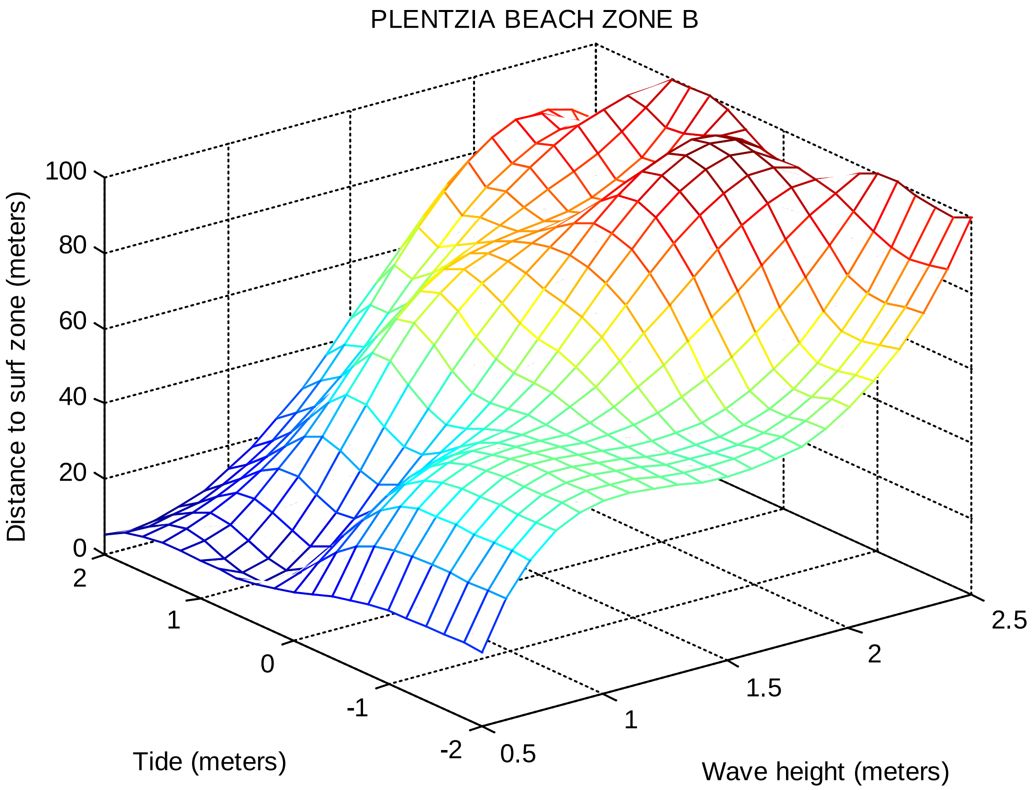

Figure 5

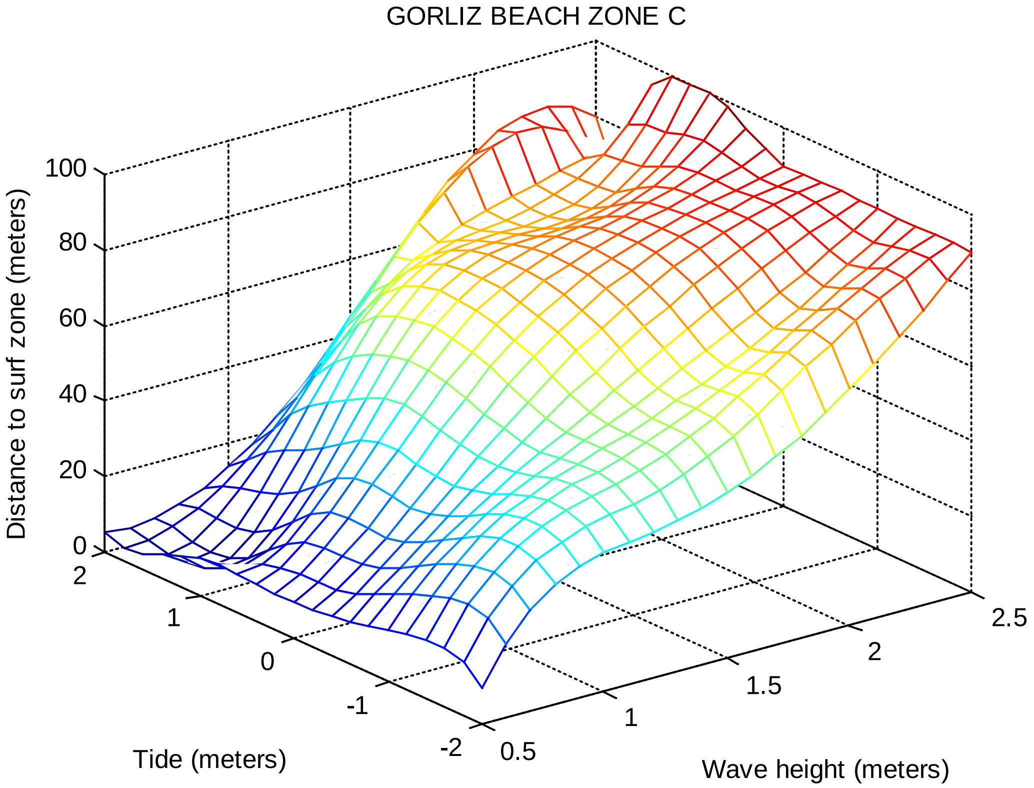

Figure 6

<u>Shoreline affected by currents (SC)</u>

The water pulled by the waves towards the shoreline is drained across the rip currents. It is flowed strongly through a relatively narrow canal (Brander et al., 2011; Dalrymple et al., 2011; MacMahan et al.,2011). Intensity may fluctuate between 0 and 1.5 m/s and width between 20 and 60 meters (Cervantes et al., 2015). Its location and strength will depend basically on the wave energy, the tide level and the bottom shape (Woodrofe, 2002). Therefore, they are always moving throughout time and, consequently, they are difficult to be recognised at times even by lifeguards (Fletmeyer and Leatherman, 2010). In this way, printed information seems to be effective in warning beachgoers about calm-looking rips (Hatfield et al., 2012). Bearing in mind that the very current tends to mould the sandy bottom, it can be said that the current and the bottom shape are interrelated. Rip currents are really a danger for bathers (including surfers) within the surf zone (Scott et al., 2008; Brander et al., 2011; Caldwell et al., 2013; Brannstrom et al., 2014; Woodward et al., 2015; Klein et al., 2003; Hartmann, 2006; Scott et al., 2007; Short, 2007; Gensini and Ashley, 2010; Arun Kumar and Prasad, 2014; Arozarena et al., 2015). The consequence for beachgoers is the reduction of the bath zone in safety terms or, what it is the same, the shortening of the usable shoreline. In addition to the rip currents, the tidal current located in the river mouth affects also part of the beach (Plentzia A). Tidal current is particularly high during the intermediate tide and may become extreme in neaps. The data related to the shoreline affected by currents (rip and tidal currents) was collected by the lifeguards and are shown in figures 7, 8 and 9.

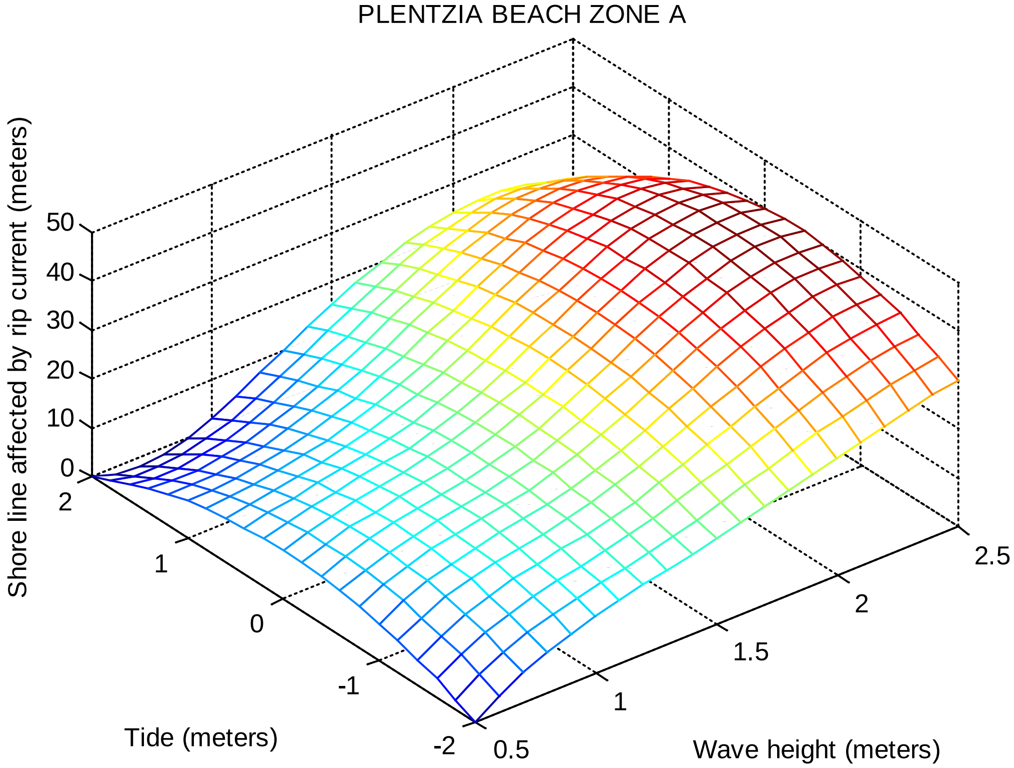

Figure 7

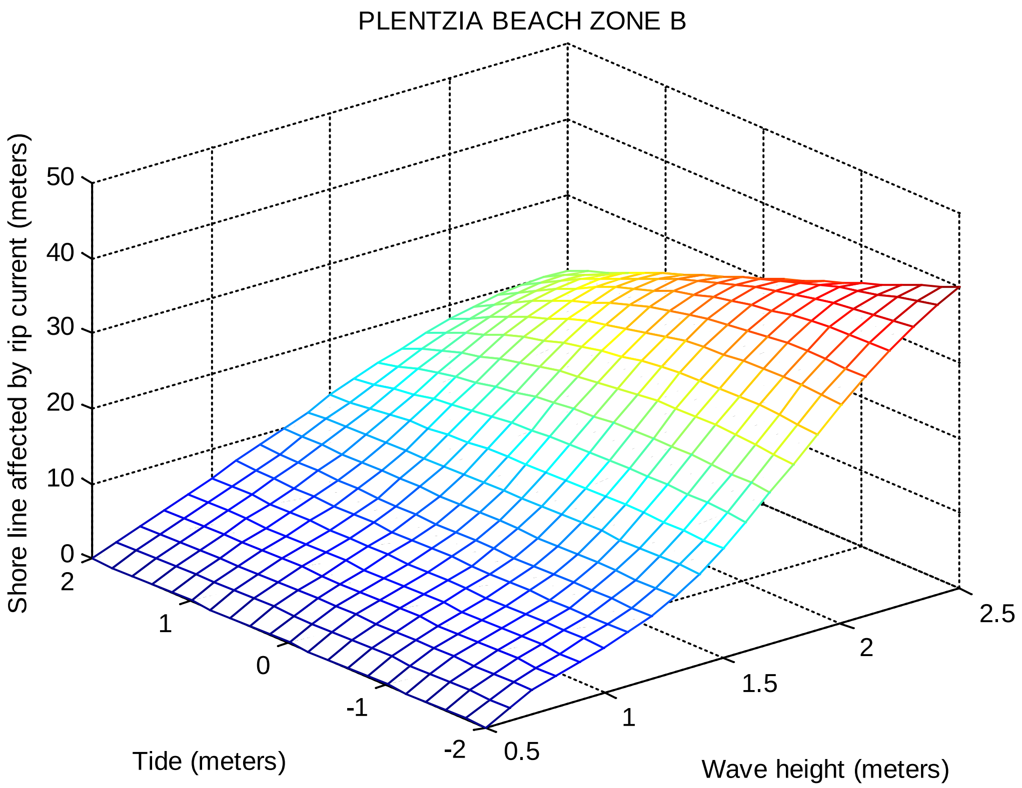

Figure 8

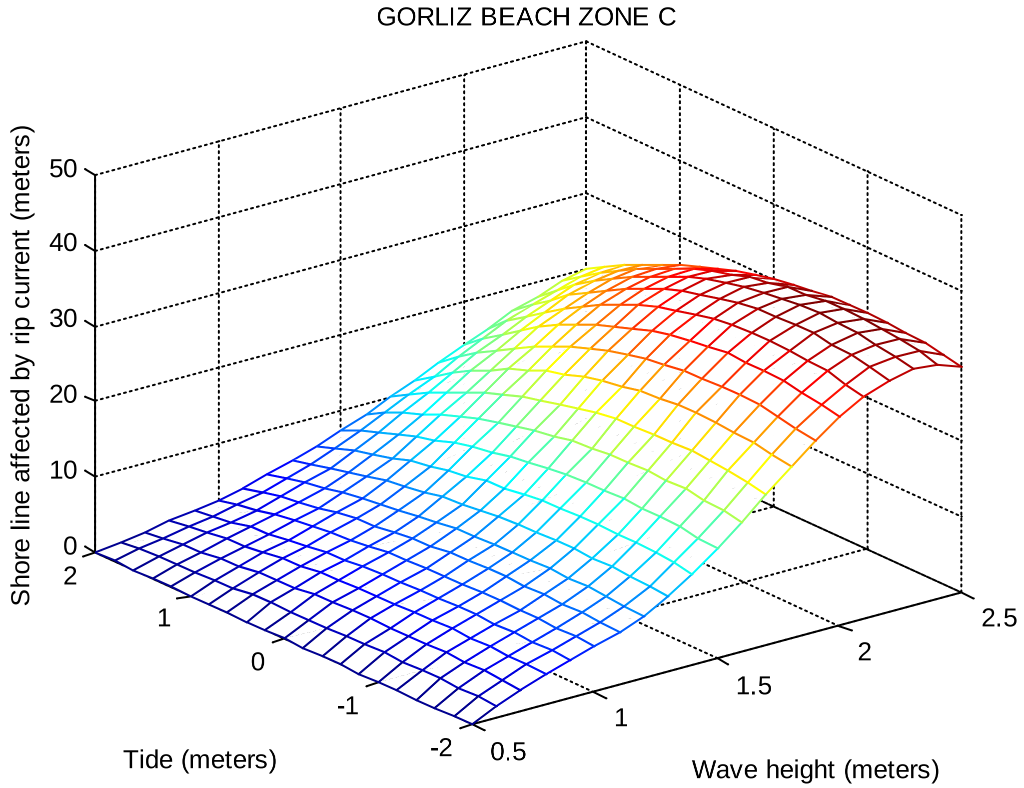

Figure 9

Penetration coefficient (PC)

The occupancy of SBZ is not always uniform. Bathers' density and movements are different depending on the wave height. The observation carried out in Biscay beaches shows how the bathers penetrate into the sea with respect to the line of breaking waves. Obviously, they will go deep into sea beyond the breaking waves when their height is very low and, on the contrary, they will not reach the breaking waves when their height is high. The way of penetration changes to wedge shape when the wave height is higher than half meter. As for occupancy density, bathers are more dispersed when the sea is rough. This method is applicable only to small beaches where there are reduced extensions for bathing. Figure 10 shows how the bathers are occupying the sea in Biscay beaches.

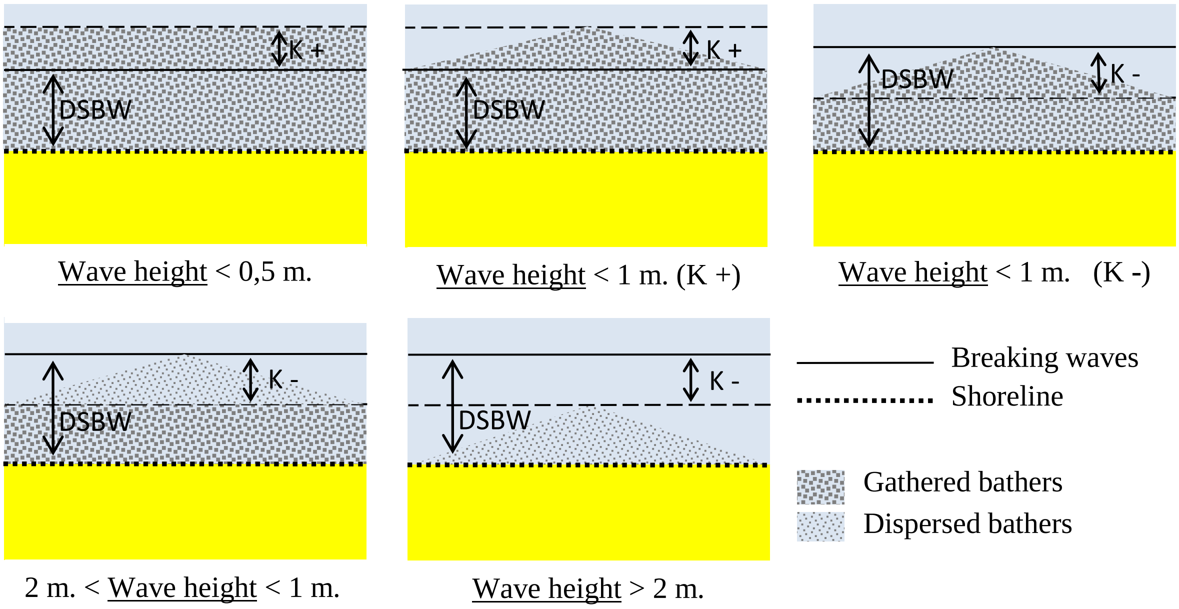

Figure 10

The variable K and the occupancy density will determine the penetration coefficient PC which will be applied to DSBW to calculate the dimensions of the SBZ. Figures 11, 12 and 13 show the values of K collected by the lifeguards after soft data processing. The variable K is considered positive when bathers penetrate beyond the breaking waves and negative in the opposite case. The occupancy density is twice as big when bathers are gathered than when they are dispersed. On the other hand the penetration coefficient (PC) is obtained as shown in table 6 where the symbol H indicates the wave height.

Table 6. Penetration coeficient

H < 0,5 m	H < 1 m	1 m < H < 2 m	H > 2 m
$PC = K$	$PC = \frac{1}{2}K$	$PC = \frac{3}{4}K$	$PC = +\frac{K - 3 \cdot DSBW}{4}$

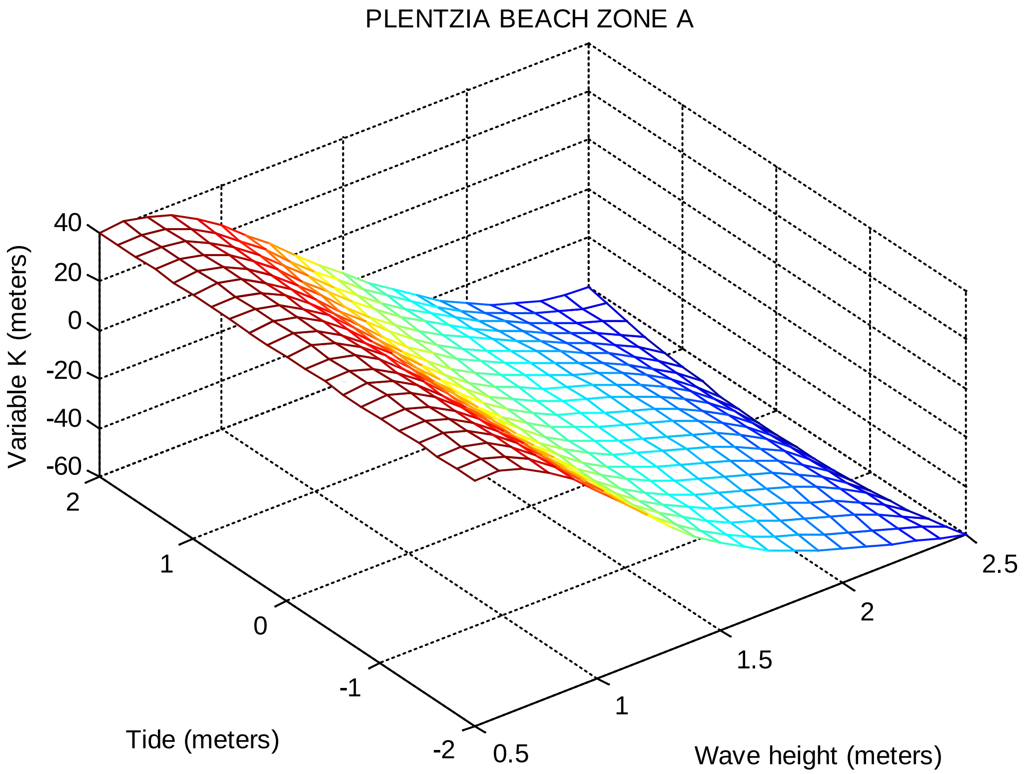

Figure 11

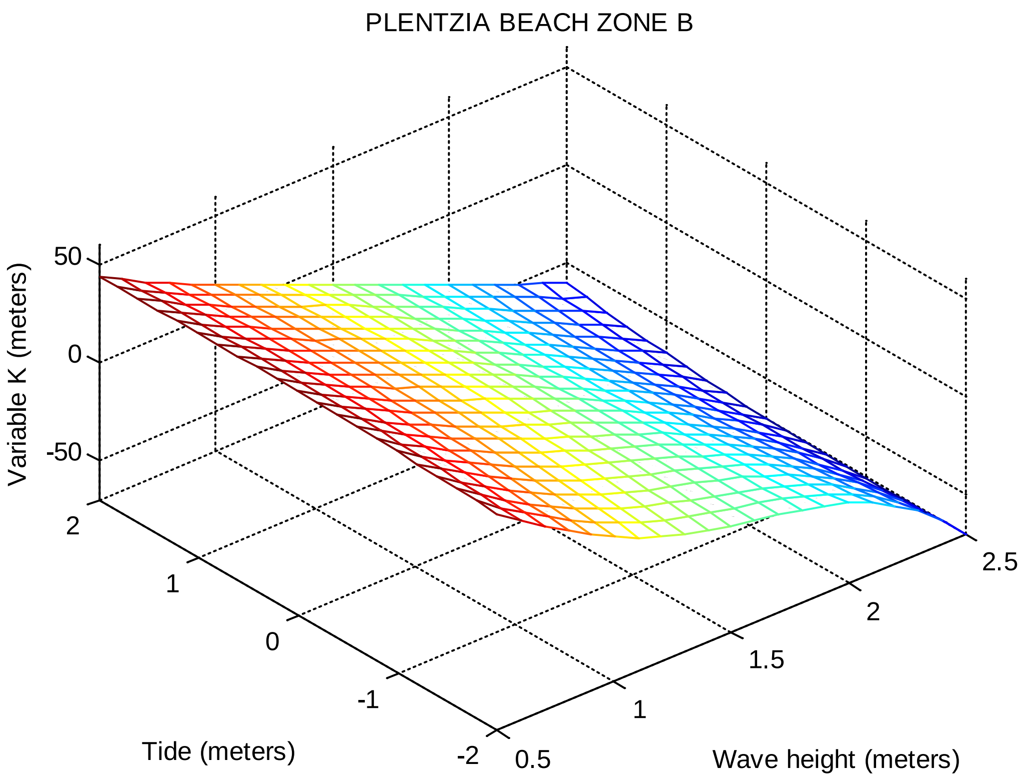

Figure 12

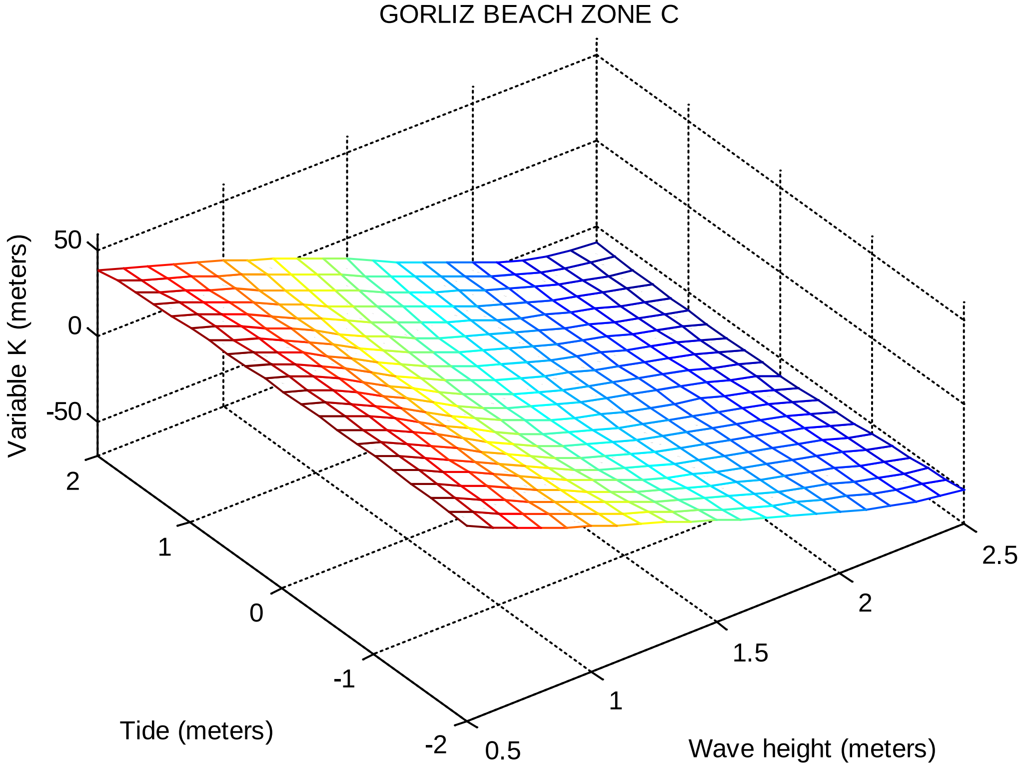

Figure 13

Results

3.1 Usable shoreline (USL)

The part affected by the tidal and rip currents is deducted from the beach shoreline, as well as the rocks and/or artificial installations, with the purpose of eliminating the unsafe areas not usable for bathing. This dimension is the usable shoreline (USL) the value of which is calculated by the formula included in table 7. Moreover, the results corresponding to variations in USL due to tidal and waves effects are shown graphically in figures 14, 15 and 16. Figure 17 shows a beach and indicates how the USL is calculated.

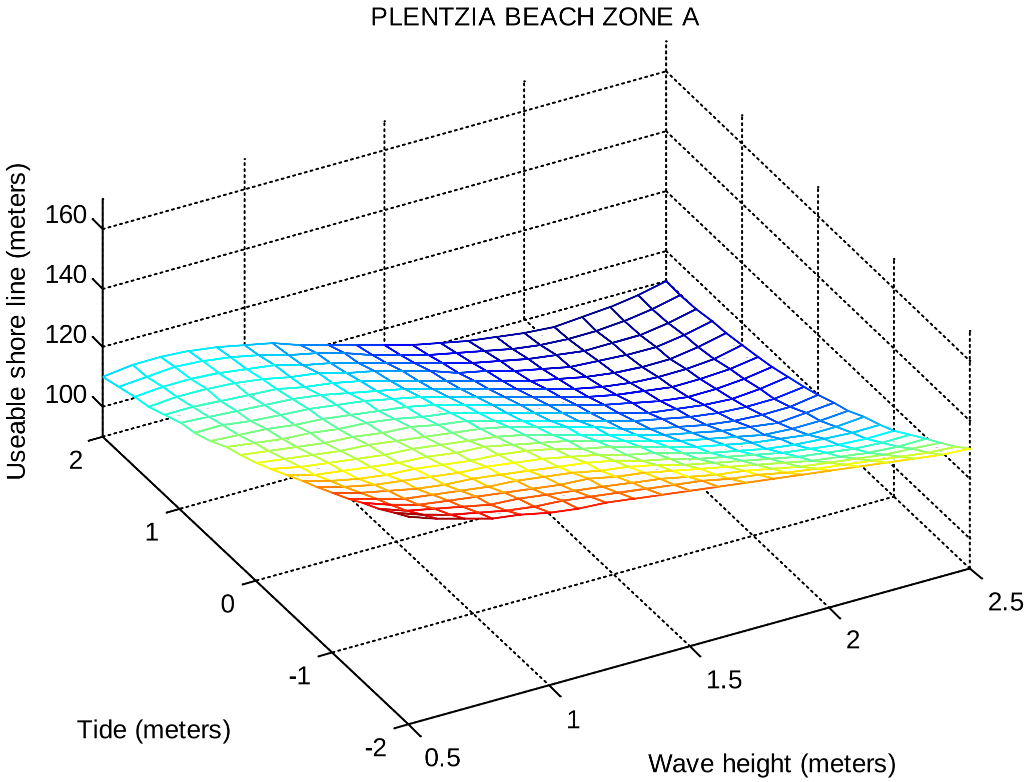

Figure 14

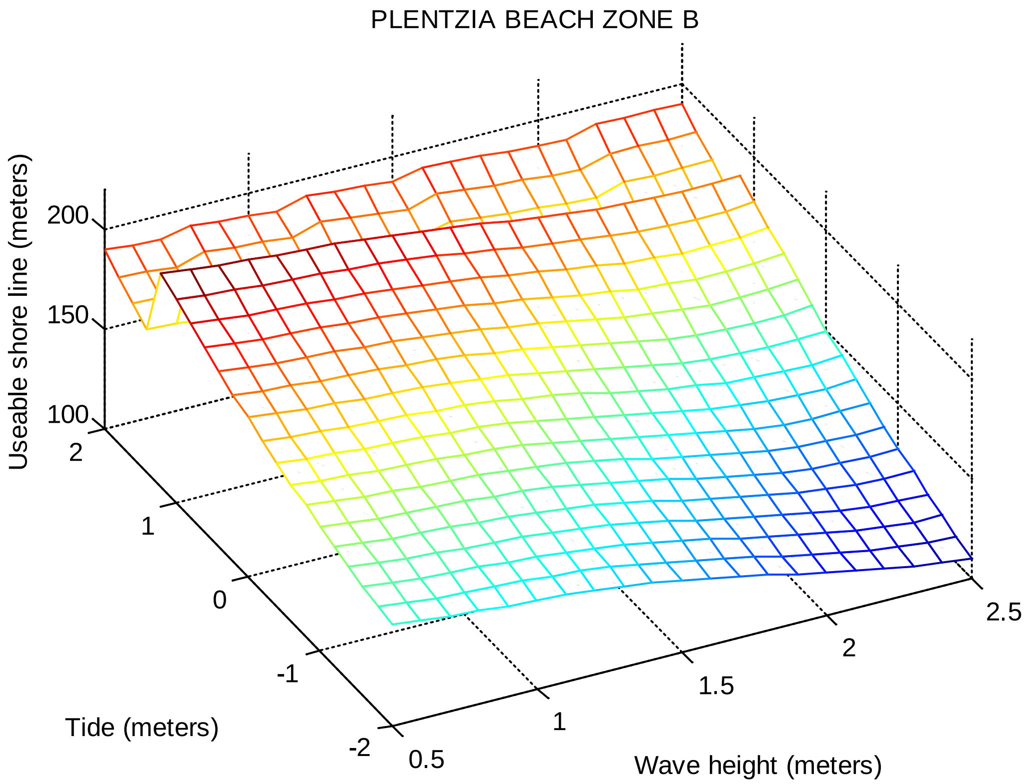

Figure 15

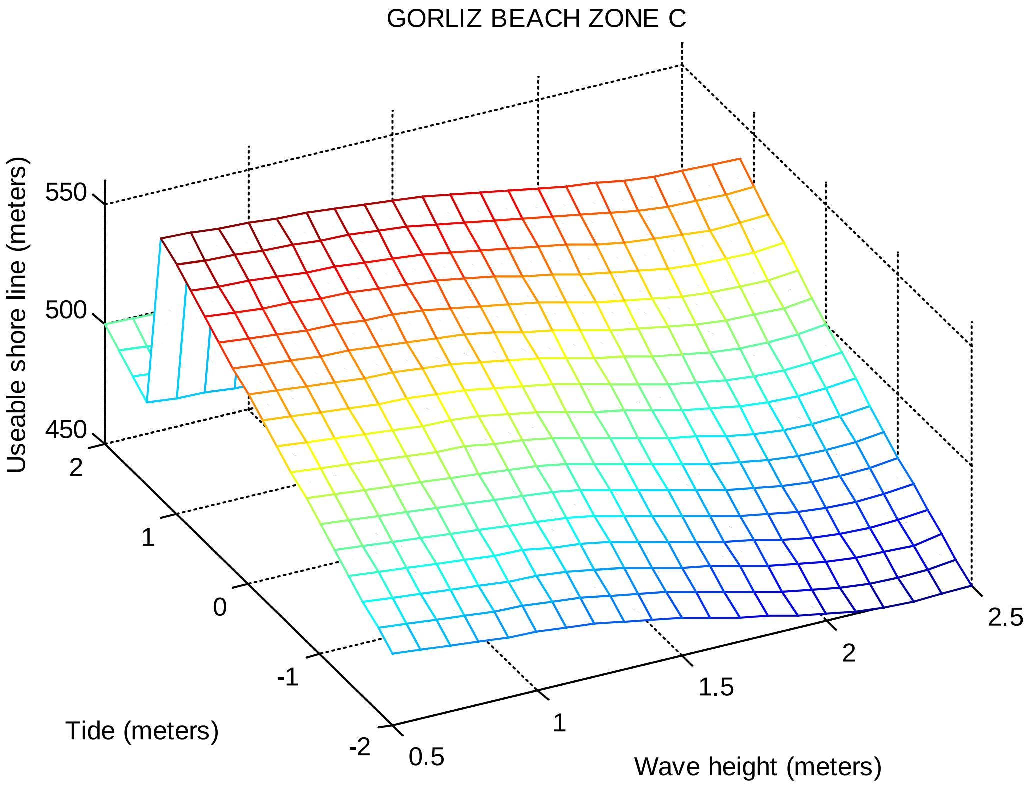

Figure 16

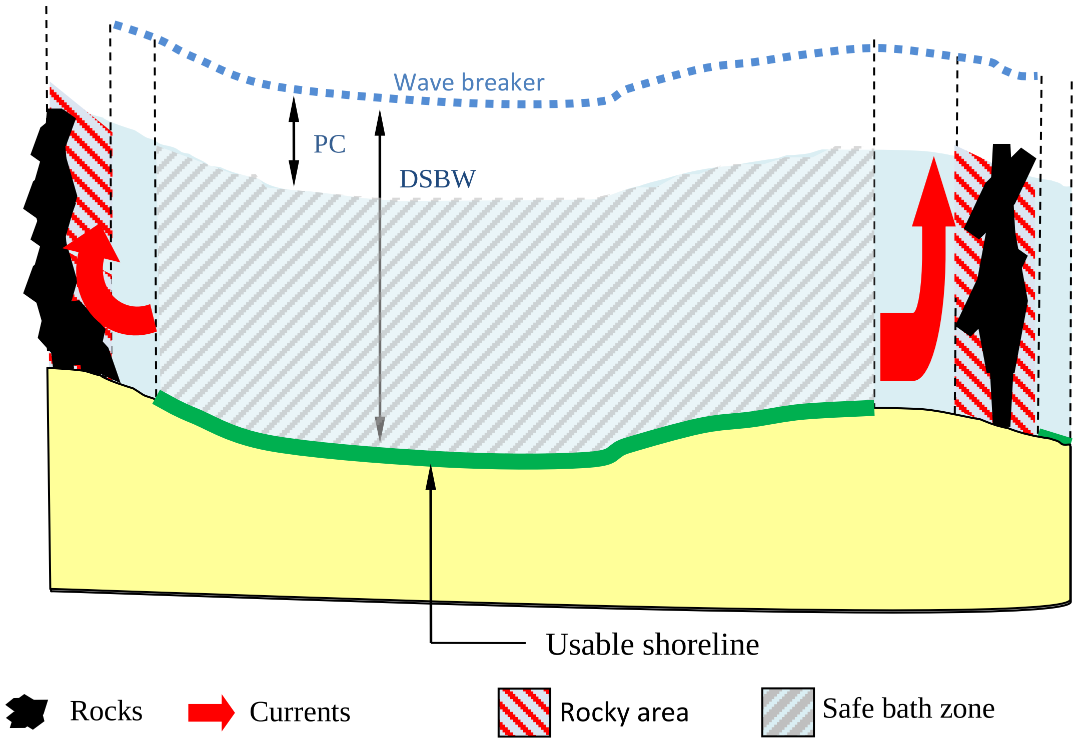

Figure 17

3.2 Safe bath zone (SBZ)

SBZ is the water area where the bathers can swim and refresh safely. It is a zone placed far from the currents, obstructions, rocks and other dangers. Moreover, the areas where the concentration of bathers is low are excluded from the SBZ and, in this way, lonely bathers are avoided. In case the beach is semicircular, the SBZ is reduced depending of the radius as it is shown in figure 18. Formulae to obtain the SBZ are given in table 7. The results of SBZ in square meters for the three beach areas are given in figures 19, 20 and 21.

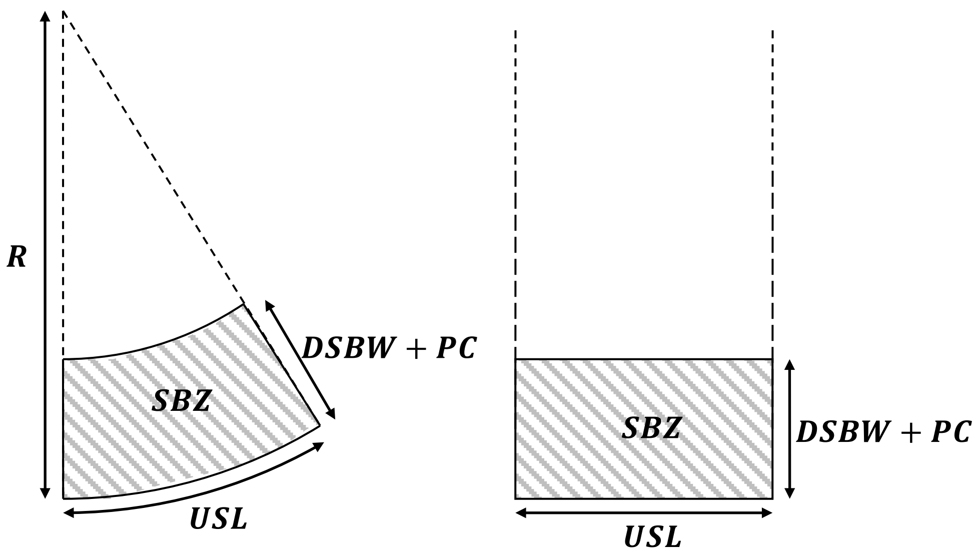

Figure 18

Table 7. Formulae related to USL and SBZ

USL (meters)	$USL = SL - SC - O$
SBZ for semicircular beach (sq. meters)	$SBZ = \frac{USL}{2\pi R} \cdot \pi \cdot [R^2 - \{R - (DSBW + PC)\}^2]$
SBZ for rectilinear beach (sq. meters)	$SBZ = USL \cdot (DSBW + PC)$

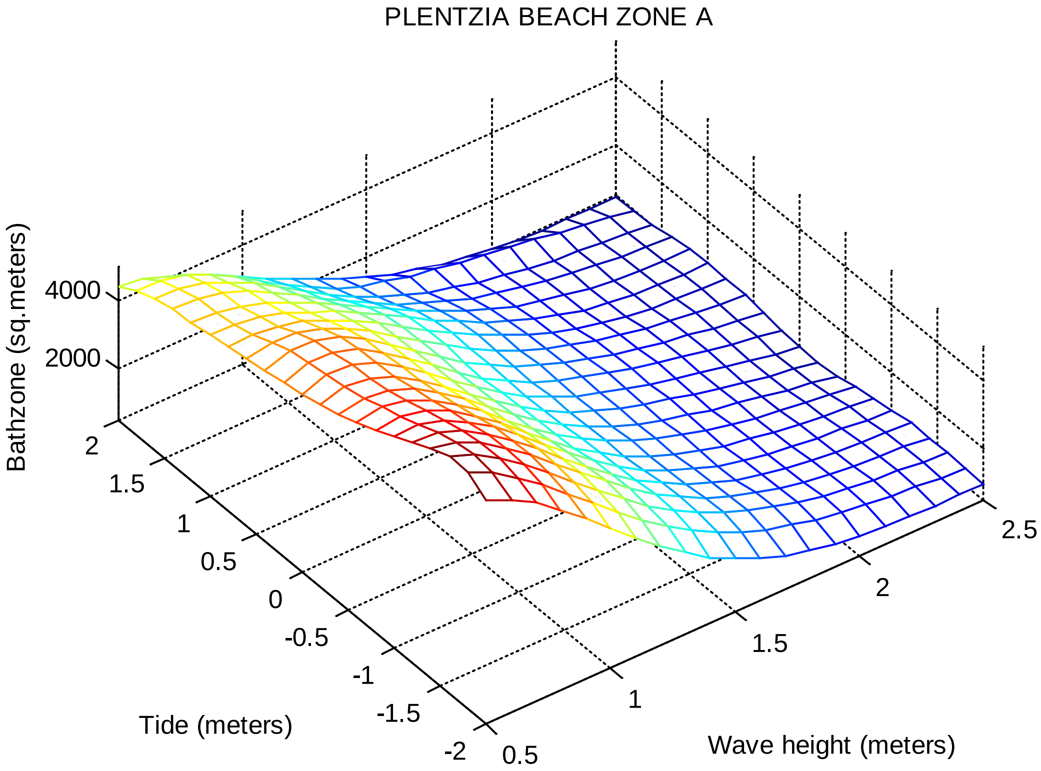

Figure 19

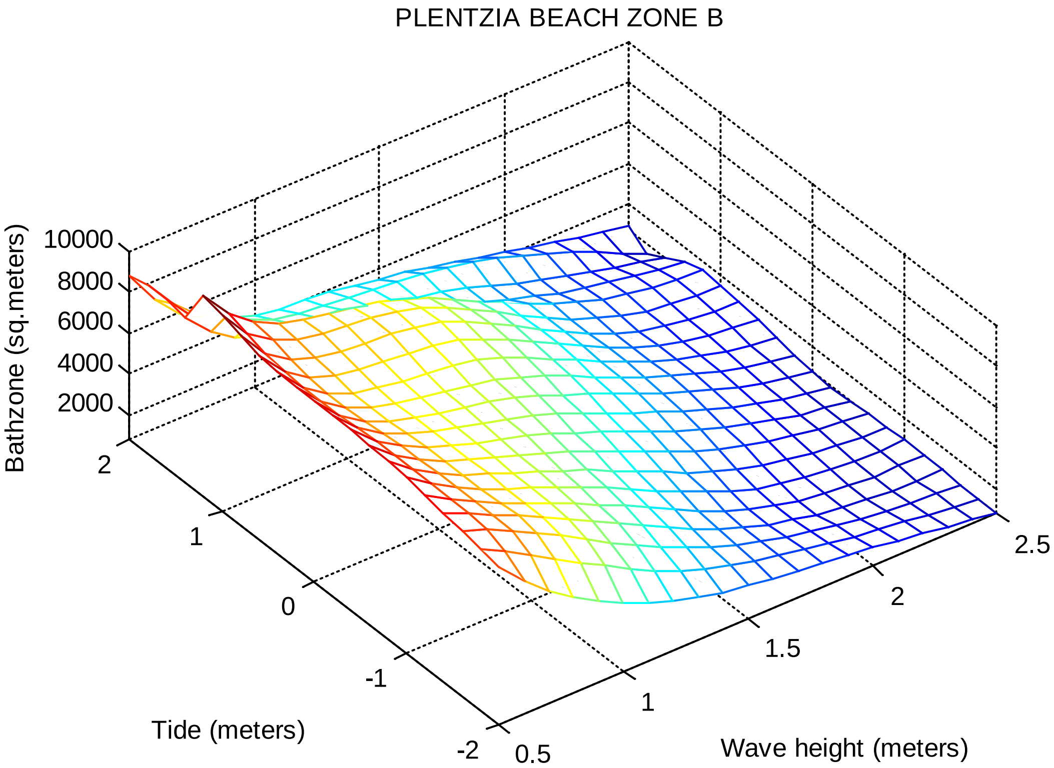

Figure 20

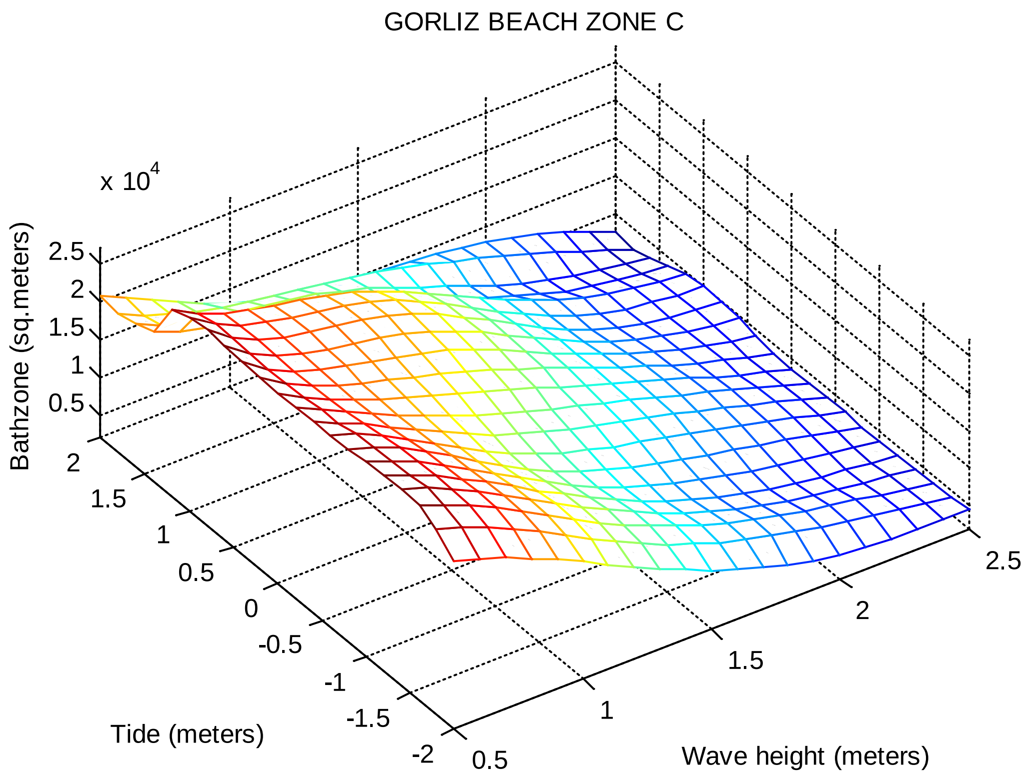

Figure 21

3.2 Maximum number of bathers within the SBZ (MAXBATHERS)

The maximum number of bathers placed instantly in water may be calculated depending on the space occupied by each one. In this way, an average of overcrowding may be considered when one beachgoer occupies less than 22.06 sq. m. according to studies made at a beach located in Baisha (Tahiland) using the socio-cultural carrying capacity methodology (Chen and Teng, 2016). However, that is applicable to the full extension of beach, including land and water. After the observations carried out in the summer of 2016, the corresponding water area for one bather, different from wader or surfer, would be around 9 sq. meters, which is in line with the studies carried out in other beaches (Palomino de Dios et al., 2012). For instance, on 17th July 2016, when the temperature was exceptionally high (more than 30ºC) and the sea calm (wave significant height 0.8 m.), the number of bathers in water was 810 for Plentzia A and B jointly at 13:50 hours and 717 for Gorliz C at 14:10 hours. Nevertheless, bathers' capacity depends on the time that bathers remain in water and, according to studies carried out in Australia, the average time in water for all kind of bathers (including waders and surfers) is 19 and 11 minutes for males and females respectively (Morgan et al., 2009). Of course, this time in water will depend on the atmospheric variables. In table 6 the results of MAXBATHERS for each beach zone is provided according to the ratio of $9m^2$ per bather.

Tabla 6. MAXBATHERS

	Plentzia A					Plentzia B					Gorliz C				
	Wave Height					Wave Height					Wave Height				
Tide	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**
2.0	494	343	156	64	49	979	481	387	248	105	2312	1433	1061	879	271
1.8	530	377	191	119	55	1004	537	449	309	33	2262	1696	1381	879	244
1.6	554	407	198	101	60	1003	591	448	253	92	2314	1850	1375	704	329
1.4	568	432	220	109	68	985	630	474	260	148	2420	1943	1410	752	420
1.2	577	454	242	111	76	1184	792	591	288	176	2959	2359	1720	885	540
1.0	585	476	259	113	82	1151	804	611	275	165	3061	2411	1784	876	563
0.8	594	495	266	120	81	1118	792	613	273	155	3092	2410	1806	890	561
0.6	605	511	266	129	76	1091	766	600	275	140	3077	2370	1789	919	531
0.4	616	520	263	137	68	1075	742	580	277	119	3050	2313	1745	953	485
0.2	626	524	261	141	60	1068	726	557	273	98	3029	2257	1684	980	439
0.0	637	527	262	139	55	1067	718	535	261	83	3018	2209	1613	994	413
-0.2	652	531	264	137	56	1068	715	512	244	77	3016	2170	1532	995	415
-0.4	671	538	265	136	63	1067	711	485	224	81	3026	2143	1440	977	423
-0.6	694	548	266	137	75	1062	707	455	201	89	3044	2133	1348	923	428
-0.8	721	559	269	138	88	1054	703	425	174	97	3067	2144	1278	834	433
-1.0	751	569	273	140	100	1042	699	397	149	101	3090	2173	1248	740	440
-1.2	781	577	279	142	107	1026	693	372	135	99	3109	2206	1255	692	448
-1.4	811	577	283	149	109	1005	682	348	137	93	3117	2226	1289	730	459
-1.6	832	568	282	154	109	983	652	325	153	87	3083	2210	1310	794	471
-1.8	829	547	267	148	107	960	584	299	172	86	2962	2128	1261	780	483
-2.0	788	514	229	121	106	940	456	268	187	91	2711	1952	1089	584	494

Conclusions and further works

Sandy beaches along Biscay coast are really small and opened to swell from the Norwest. The demography pressure during the summer time causes crowded beaches in those days under good atmospheric conditions. The overcrowding, together with the special increase of surfers and the proliferation of surf schools, may bring the beach water to exceptional conditions in terms of safety. Therefore, it is necessary to calculate the bathers' capacity to carry out a special safety distribution of bathers (including surfers). Some researches on surfing tourism management have been carried out in other countries (Towner, 2016). The sudden variations in sandbars due to the dynamism of beaches morphology make the beach capacity change in short periods of time (Lippmann and Holman, 1990; Kuriyama, 2002; Martinez and Salinas, 2009). The algorithm presented in this paper provides us with a rapid tool to calculate the area of the SBZ through the input of the distance from the shoreline to the breaking waves. In this way, the Biscay Regional Council Office has provided the local governments with this tool in order to regulate and govern the beach water distribution for different groups: bathers and waders, free surfers and beginners belonging to surf schools and camps. Another step to be taken in future would be the standardisation of an international flag marking system to carry out the safe distribution of bathers. The implementation of an international standardised beach flag system and communications messaging would improve understanding of safe zones for bathing (Sherker et al., 2010; Gallop et al., 2016)

Ethical statement

This research has been carried out in accordance with the ethical guidelines of the respective authors' instructions. The research is original having not been previously published and is the result of the authors' intellectual thought.

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