The Beach Crowding Index: a tool for assessing social carrying capacity of vulnerable beaches.

Journal:	*The Professional Geographer*
Manuscript ID	Draft
Manuscript Type:	Regular Manuscript
Key Words:	BCI, beach management, carrying capacity, crowdedness, Geographic Information System

Introduction

Coastal areas are fragile environments which are under high pressure due to tourist activity and unsustainable practices (EEA, 1999). In particular, beaches are understood to be highly vulnerable and prone to degradation by crowds of visitors during the bathing season (Benoit and Comeau, 2005). Carrying capacity is a useful concept for beaches and coastal areas because it provides a better understanding of how damageable and protected areas and can be managed (WTO, 1981). Physical carrying capacity refers to the maximum number of visitors a beach can receive without being negatively affected by physical, biological and management issues such as erosion, vegetation degradation or accessibility; social carrying capacity refers to the maximum amount of visitors at which beachgoers themselves feel comfortable (Cifuentes et al., 1999; Silva, 2002; Zacarias et al., 2011).

Social carrying capacity is a dynamic concept because people's perceptions are cultural responses that may vary quickly, as has been found at Mediterranean beaches (Breton et al., 1996). Variations in the experience of the recreational infrastructure can be motivated by a number of components such as personality type, sex, age, group size, personal background and so forth (De Ruyck et al., 1997). People's perception of crowding is fundamental to their perception of a beach's quality (Ariza et al., 2008; Silva and Ferreira, 2013; Lucrezi et al., 2016), especially if the beach is in a protected area (Roca and Villares, 2008; Ribeiro et al, 2011).

A number of procedures have been undertaken in order to assess social carrying capacity, with greater or lesser degrees of success (Snowman, 1987; Cifuentes et al., 1999; Saveriades, 2000; Roca et al., 2008; Kalish, 2012). Overall, these approaches focus on beachgoers' perceptions of crowding through questionnaires or interviews; additionally, external factors such as entrances to the beach, access to amenities or tourist accommodations may also be considered (De Ruyck et al., 1997; Silva, 2002; Zacarias et al., 2011). In a nutshell, any method's purpose is to determine how many people can fit comfortably on a beach (Williams and Lemckert, 2007). With this in mind, several crowding thresholds use minimum and maximum scores for different kinds of beaches (urban, semi-urban, natural); for example, a set of over a dozen studies on Mediterranean beaches used a range of 6 to 25 users per 100m^2 of sand (Roca et al., 2008). Nevertheless, many approaches still fail to provide a comprehensive picture because they focus solely on beachgoer numbers or perceptions whilst ignoring their spatial distribution on the beach.

The main objective of this paper is to introduce the Beach Crowding Index (BCI), an index for assessing social carrying capacity by taking into account beachgoers' spatial distribution on vulnerable beaches. Four beaches in protected areas were surveyed weekly from June to September (that is , during the area's tourism high season), questionnaires were undertaken and spatial distribution was analyzed using GIS. The study sought to answer four main research questions: (1) how many people use beaches throughout the summer season?; (2) where are the beachgoers located on the beach?; (3) which spatial patterns can be observed throughout the summer season; and, (4) what is the social carrying capacity based on the number of users and their distribution?

Research methods

Fieldwork was undertaken weekly during the summer season of 2015 (June, July, August and September). Beaches were surveyed every Thursday. Thursday was chosen because it is representative of any week-day; week-ends were assumed not to be representative of a normal week-day but rather were classified as being like any week-day in August when crowd rates are higher.

Data was gathered by systematic sampling. A transect along the beach's shoreline was monitored at the same hour every Thursday, and the location of beach-goers was marked in a 1:2.500 orthophoto. For better referencing, a 100*100m grid was placed in the orthophoto and all relevant landmarks, such as beach entrances, paths or kiosks were highlighted. The data was then digitalized and analyzed in ArcGis 10.3 (ESRI, 2015). Surveys were undertaken simultaneously at midday on each beach; this time was chosen because it matched the most crowded time of the day (Silva, 2002; Ribeiro et al., 2011). This procedure turned out to be easier and more straightforward than any other procedure based on GPS or video recording (Jiménez et al., 2007; Huamantico et al., 2016), is regarded as very reliable and is related to the PAOT (people at one time) procedure (Zacarias et al., 2011). Forty-two interviews with beachgoers were carried out during the four weeks of August, the most crowded month of the period studied. Beach-goers were asked closed and open questions to assess their perception's of crowding and response towards crowding (Silva, 2002; Williams and Lemckert, 2007).

The BCI is an index consisting of three weighted sub-indexes. The first sub-index estimates crowding at the immediate level (100m^2), the second sub-index estimates crowding at the neighboring level (800m^2) and the third estimates the number of people on the entire beach (Figure 1). The GIS procedure counts the number of beachgoers in 100m^2 (10m*10m) blocks (De Ruyck et al., 1997) along the beach and estimates crowding on the basis of four categories: 1: 5.0m^2 of sand or less per user; 2: between 5.1 and 7.0m^2 per user; 3: between 7.1 and 9.9 m^2 per user; and 4: more than 10.0 m^2 of sand per user (Silva, 2002; Roca et al., 2008; Ribeiro et al, 2011; Pessoa et al., 2013). A second crowding sub-index is used to estimate the number of beachgoers surrounding each 100m^2 block; this is because an uncrowded quadrat may be surrounded by crowded quadrats, thus making the former seem crowded. For that purpose only contiguity between sides (rook contiguity) was considered, as contiguity at cell corners (king contiguity) was not considered relevant. The resulting analysis lowered the score of blocks neighboring a crowded block by one point: blocks with 4 points which were next to blocks scoring 3 became 3, and so on. A third sub-index calculated the whole number of beachgoers on the beach's entire surface area (Silva et al., 2007; Rajan et al., 2013). Four categories were formed on the basis of what beachgoers considered to be crowded: 1: less than 9.9m^2 per user; 2: between 10.0 and 29.9m^2 per user; 3: between 30.0 and 49.9m^2 per user, and 4: more than 50m^2 per user. Finally, a weighted algorithm was applied to calculate the BCI, which consisted of 40% of the final score for the first comfort sub-index and 30% for the second and third, as the latter two are reported to have less influence on the sensation of overcrowding (Roca et al., 2008). Scores were classified on the basis of beachgoers' opinions and field work: a poor BCI score is related to a perception of available sand $\leq$ 2.0m^2/user; an acceptable score to 2.1 -2.5m^2/user; a good score to 2.6-3.0m^2/user; and a very good score to $\geq$ 3.1m^2/user.

Study area

The research was conducted on four beaches in protected areas on the Mediterranean Spanish coast. Muntanyans is a long (3km) beach located between two major coastal resorts and surrounded by camping parks that together host over 70,000 domestic and international tourists in the summer season; Cala Fonda is a small (150m long, 40m wide) pocket nudist beach which can only be reached by sea or by a 25 minute walk through a protected forest; Riumar is an embayed beach 1km long and 60m wide enclosed by sea dunes near a small beach resort (about 1000 international tourists in the high season); Trabucador is a long (about 6km) remote exposed beach consisting of a 130m wide spit popular with nudists, families and surfers (Figure 2).

The beaches have similarities (e.g. they are sandy beaches, they are Blue Flag awarded) and differences (e.g. some beaches are in a small pocket bays while others are exposed, some are easy to reach from resorts while others are quite remote). All of them are in protected areas recognized by the European Union and other international organizations, and they appear as attractions in all touristic brochures for the region (Tripadvisor, 2016).

Results and Discussion

Beaches and beachgoers' preferences

Fieldwork identified the number of beachgoers throughout the bathing season, with the highest concentration being in August. The number of tourists varied markedly during the period studied depending on the beach: Muntanyans beach received the highest number of visitors (14,656 beachgoers) whereas Cala Fonda hosted the lowest (390).The number of people on the beach changed at different times too: Muntanyans received most visitors in the 5th week of July (2,026) and the 3rd week of August (2,091) followed by Trabucador in the 2nd (678) and 3rd week of August (690). Higher and lower frequentation rates are related to a number of factors such as summer storms (e.g. 1st week of July, 2nd week of August) or the most common holiday patterns (i.e. 4th week of August and 1st week of September) (Figure 3). According to Zacarias et al. (2011), the number of beach users and the perceived sense of crowding is a key factor to ensuring proper beach management and improving its quality. Research on sandy beaches shows that the more the number of visitors increases the more beach's quality decreases, because users do not feel comfortable on it and social and environmental items are under pressure (Ariza et al., 2008; Huamantico et al., 2016).

The maximum number of visitors a beach can accommodate is commonly used as an indicator of overcrowding and carrying capacity, at least from a theoretical point of view (Silva et al., 2007; Rajan et al., 2013). But beachgoer distribution does not follow a uniform pattern all over the beach and, hence, a universal density value does not seem to be appropirate (Silva, 2002). Beachgoer density and sand availability are correlated, and spatial analysis shows distribution patterns. Most beach-goers concentrate in the first 20m from the shoreline (e.g. Muntanyans 82%, Riumar 75.6%) with a small number between 20 and 35m (e.g. Muntanyans 16.3%, Riumar 16%). After the first 25m from the water's edge, beachgoer concentration decreases irregularly and only a small number of visitors (<0.05%) are found beyond 100m. This is consistent with the seminal study by Alemany (1984), which claimed that most of the beachgoers concentrate on the first 30m from seashore. However, on more crowded days beachgoers tend to occupy areas to the back of the beach (e.g. in the 3rd week of August 65% of the beachgoers were between 35 and 60m from the seashore at Muntanyans), thus fully occupying the beach. Fieldwork revealed that on windy days with a rough sea (e.g. 1st week of July) beachgoers also tend to stay beyond the first 20m from the shoreline. It was also noticed that beachgoer distribution was conditioned by games such as volleyball, football or Frisbee, which usually take place between 40 and 65m from the water's edge and tend to disappear when the beach becomes crowded. Games are less common on more frequented beaches than on beaches with fewer people (e.g. Riumar, Table 1) which reveals a certain level of self-regulation among users. This aspect is highly important as it reveals that the quality of beaches is related to the behavior of users (Roca and Villares, 2008; Lucrezi et al., 2016), and that spatial patterns may therefore be derived from these behaviors.

Access points and facilities such as parking lots or kiosks also play an important role in beach-goers distribution (Jurado and Pérez, 2014). As general rule, visitors prefer not to be far from access points but also not too close as indicated by the higher values in the buffer zones between 20m and 30m (Table 2), although significant differences can be observed depending on the nature of a beach's access points. Beyond 35m, no evident distribution appears as different access or facilities buffers can merge, and visitor distribution randomizes. When a beach has a single or main access (e.g. Cala Fonda), the spatial pattern reveals an even distribution from a central point; when a beach has no definite access point (e.g. Trabucador) no patterns can be distinguished. Clearer patterns are observed on more frequented beaches (e.g. Muntanyans) but if crowding occurs, patterns fade as people fill any available empty space.

Overall, it can be stated that visitor distribution is not random (De Ruyck et al., 1997) and that spatial patterns can be observed depending on beach morphology, services or equipment. Furthermore, visitor distribution varies according users' preferences (Breton et al., 1996; Roca et al., 2008) and some authors have pointed out the need to differentiate between types of user (Williams and Lemckert, 2007) in order to correctly understand their spatial location and their meaning when assessing crowding.

The results of the beachgoer interviews turned out to be less homogeneous than expected and revealed great variations depending on the beach where they were interviewed and their profiles. In almost all cases (88%) respondents stated that they felt comfortable with the number of people on the beach at that time. In 85.7% of cases, they said that the number of people they encountered was perfect as it was, although in 57% of cases they wished that fewer people were present at that particular moment, which indicates user's preferences but, at the same time, shows that they are willing to accept the situation as it is. Regardless of the number of beachgoers, 95.2% of users said that they would go back to the beach the following day if the number of users were the same. As Zacarias et al. (2011) noticed, local users tend to prefer lower densities of beachgoers whereas foreign users seem unperturbed by higher densities. However, both local and foreign users on nudist beaches always praised lower densities (41.7%) and 75% of them stated their intention to go elsewhere if the beach became overcrowded; when they were asked why, some of them clearly stated that they did not like it when other people were too close to them.

Most of the beach-goers (76.2%) found difficult to calculate the number of people they thought the beach could accommodate without feeling uncomfortable, but they had an opinion about what they would do if the beach became overcrowded, which means that they were concerned about crowding. In fact, more than two thirds of users reported to move to a less dense spot on the same beach or to another beach, and 23.8% stated that they preferred to be at home rather than on a crowded beach. The beachgoers' difficulties in determining the user density on a beach may be related to poor spatial awareness, because on pocket beaches such as Cala Fonda, users' responses were precise and consistent with each other. In most cases (66.7%) respondents stated their intention of avoiding or escaping crowds; in general, the more isolated or unspoilt the beach the more consistent were the beachgoers' responses. Lonely beaches, such as Trabucador, seemed to be chosen especially for this reason; comments such as "now I'm feeling fine; there aren't too much people" were recurrent. In 4.8% of cases, and only on Muntanyans beach, beach-goers stated that they would feel better with more people. This low percentage of gregarious users differs from the responses given at urban or developed beaches, where beach-goers appreciate a minimum threshold of users (De Ruyck et al., 1997), and demonstrates a distinction with regard to vulnerable beaches.

Crowding index

The crowding index synthetizes the size of the beach, the number of users and their location on the beach. The first sub-index shows an immediate comfort level and gives highly accurate results regarding the number of beachgoers (i.e. 100m^2 blocks). Higher scores occur in Muntanyans where on average 2.26% of quadrats (that is 0.21% of beach's surface) hold one or more users in 5m^2 of sand throughout the bathing season. Lowest crowdedness scores happen in Cala Fonda, where on average 30.16% of the beach's surface offers more than 10m^2 of sand per user when the beach is crowded throughout the bathing season. As a reference, Alemany (1984) suggested a threshold of 5m^2/user for Mediterranean beaches, Ariza et al. (2010) defined an optimal situation when sand availability was greater than 8m^2/user on urban beaches, and Roca et al. (2008) gathered literature suggesting values of over 20m^2/user on natural beaches. Nevertheless, high variations occur depending on the week studied since some areas can have a high concentration of beachgoers whereas at others their distribution may be more scattered, as is the case at Trabucador beach (Table 3).

People's perceptions of crowding are not limited to their immediate surroundings because even though a certain 100m^2 block may host relatively few beachgoers, if it is surrounded by overcrowded plots, those beachgoers may feel overwhelmed by neighboring users, a sentiment that a large number of respondents expressed in different ways. The second sub-index takes into account the locations of users themselves and also of those in their vicinity. This sub-index makes calculating crowding even across the beach and the results are more obvious in overcrowded situations because perception of crowding are greater. Evenness causes a decrease in the first sub-index's scores, and the average variation for all beaches is higher for class 1 (1.24 points) and lower for class 3 (0.57 points). Furthermore, some studies (e.g. Ergin et al., 2004; Williams et al., 2016) have demonstrated the importance of considering the entire beach when assessing crowding perception and coastlines on different beaches around the world, because it is the beach as a whole that shapes beachgoers' opinions. Consequently, the third sub-index considers the total number of beachgoers and the whole surface area to provide information on crowdedness for the entire beach (Silva, 2002). Taken as a whole, the commonest score is an availability of $50m^2$ or more of sand per user. On average throughout the bathing season, 34.4% of Cala Fonda beach's surface offers $50m^2$ or more of sand per user, whereas 11.8% of Muntanyans offers less than $9.9m^2$ of sand per user. Similar studies carried out on Portuguese beaches showed even broader scores ranging from 31.2 to 354.9 m^2/user (Silva 2002), whereas Ribeiro et al., (2011) calculated a minimum score of 8.96 m^2/user on average over four selected days during the tourism high season. Other research undertaken on different beaches in South Africa (De Ruyck et al., 1997) or India (Rajan et al., 2013) showed varying scores, which makes it difficult to compare and generalize results. Some authors suggested that scores below $5m^2$/user mean overcrowding and should be considered as uncomfortable (Roca and Villares, 2008; Yepes 2010 in Ribeiro et al., 2011). However, although this score appears to be illustrative, it is somewhat inaccurate because there are high levels of heterogeneity within a beach and among different types of beaches and users. Timing is also important because numbers of beachgoers vary greatly throughout the bathing season; as general rule, the bigger and more crowded the beach the more the numbers changed (Table 4).

The aforementioned sub-indexes provide partial and scaled approaches ($100m^2$ block, neighboring $100m^2$ blocks, the entire beach) to determining crowdedness on the beach. The BCI synthetizes and weights each sub-index to provide a weekly composite score of crowding across the beach in $100m^2$ blocks (Table 5). On the basis of the literature (Roca et al., 2008; Pessoa et al., 2013), users' responses and field work the following four classes were established: a poor BCI score is a perception of sand availability of $\leq 2.0m^2$/user; an acceptable score is 2.1 -2.5m^2/user; a good score is 2.6-3.0m^2/user; and a very good score is ≥3.1m^2/user. This classification ranges from more crowded to less crowded classes and considers broad enough thresholds that avoid the rigid limiting of classes in favor of tolerable limits (De Ruyck et al., 1997). For instance, for the third week of August, the most overcrowded on average for all the beaches, 302 beachgoers were counted on Riumar beach, occupying 274 out of the 2299 100m^2 plots covering the entire beach (11.92%), and enjoyed a minimum BCI rate of 1.3 (poor) and a maximum rate of 3.4 (very good). A better understanding of its significance in assessing social carrying capacity can be seen when the scores are mapped; an example for Cala Fonda is shown in Figure 4.

Crowding is regarded as an important issue in beach quality assessment, particularly for vulnerable beaches or beaches under tourist pressure (Benoit and Comeau, 2005). A number of procedures pay special attention to overcrowding as an issue that affects beach quality (e.g. Ariza et al., 2008; Lucrezi et al., 2016), and other procedures also calculate the indirect effects of overcrowding (e.g. noise) on scenery (Ergin et al., 2004; Rangel-Buitrago et al., 2013). Commonly, these procedures consider the total number of beachgoers for the entire beach (third sub-index for the BCI) and ignore their distribution throughout the beach, which, as demonstrated, can be quite heterogeneous. The BCI concentrates on beachgoers spatial position, and gives extra information about beach occupancy and users' interactions on a weekly basis, which is why it can be highly helpful when assessing social carrying capacity. Other studies that look at coastal planning or management(e.g. Jiménez et al., 2007; Huamantico et al., 2016), could also benefit from this procedure, as it builds a long term series of data that reinforces the models reliability and its trustworthiness by allowing comparison at different times (Saveriades, 2000).

Research undertaken on urban beaches (Roca and Villares, 2008) has demonstrated that overcrowding is not an inconvenience for beach-goers on urban beaches. The same cannot be said for non-urban beaches because users try to ensure sufficient distance among themselves and state their annoyance with crowds; in fact, the more natural the beach the greater the dislike of crowds. Although beachgoers' preferences are fluid cultural responses that may vary quickly (Breton et al., 1996) and beach users sometimes behave differently from their interview responses (Silva, 2002), this fact demonstrates the existence of different types of beaches and beachgoers, and their importance in beach and tourism management. For beach managers, it is important to remember that the presence of users on the beach does not mean that they are necessarily enjoying the beach, as Kalisch (2012) demonstrated on German beaches, and it underlies the fact that efforts must be made to improve beach quality.

The BCI can be applied in many ways. Because the plots analyzed are georeferenced, those areas that are usually more or less crowded can be easily located and management duties such as surveillance or cleaning can be scheduled according to needs. Coastal policies can be designed that take into account spatial analysis and carrying-capacity measurements can be introduced that consider the real impact of beachgoers on different sectors of a single beach. This is especially important on vulnerable beaches such as those in protected areas or fragile environments because they face greater threats. Some respondents suggested closing the entrance to the beach when overcrowding occurred; however, the BCI procedure means that spatial patterns can be monitored and beachgoer flows can be redirected to non-crowded areas and that therefore only overcrowded sectors need to be closed rather than the whole beach. In addition to spatial characterization, studies can also use the BCI to assess the spatial statistics of beaches. Some applied examples include regression analysis of beachgoers' opinions in relation to their position on the beach and the real world, perception of comfort interpolation, vicinity to other users and spatial interaction, advanced modelling and so forth.

Conclusion

Vulnerable beach management is a real challenge for coastal and tourism managers and the issues of crowding and social carrying capacity are difficult challenges. Beachgoers often avoid overcrowded beaches, especially on non-urban beaches, because they are usually seeking peace, tranquility and, sometimes, isolation. However, vulnerable beaches such as those in protected areas are very sensitive to crowding. As beachgoer flows increase, so too does overcrowding on vulnerable beaches and sustainable management practices need to be implemented. The BCI is a good approach for assessing and managing crowding and for preventing overcrowding, especially on vulnerable beaches. The BCI focuses on spatial analysis and gathers data throughout the bathing season, both of which bestow robustness and reliability on its results. The beaches studied gave minimum and maximum scores of 0.7 and 3.7 on a scale from 0 to 4, with considerable variety depending on the beach and week the data were taken. The BCI scores should not be understood as the maximum number of beachgoers a given beach can hold in a given area to obtain a given degree of comfort, but as a reference threshold that allows people to enjoy the beach without its quality falling below a suitable standard. Nevertheless, crowding is not the only item affecting beach quality, beach fragility and beachgoers' perceptions, and so other approaches need to be developed that complement the BCI in the process of implementing sustainable practices and achieving better beach management.

References

Alemany, J. *Estat d'utilització de les platges del litoral català*. Barcelona: Departament de Política Territorial i Obres Públiques. Generalitat de Catalunya, 1984.

Ariza. E.; Jimenez. J.A.; Sarda. R. Villares; M. Pinto. J.; Fraguell. R.; Roca. E.; Marti. C.; Veldemoro. H.; Ballester. R.; Fluvia. M. 2010. Proposal for an integral quality index for urban and urbanized beaches. *Environmental Management*. 45: 998-1013. doi: 10.1007/s00267-010-9472-8

Ariza. E.; Sardá. R.; Jiménez. J.; Mora. J.; Ávila.C. 2008. Beyond the performance assessment measurements for beach management: Application to Spanish Mediterranean beaches. *Coastal Management*. 36(1): 47-66. doi: 10.1080/08920750701682023

Benoit. G., and Comeau. A. 2005. *A Sustainable Future for the Mediterranean: The Blue Plan's Environment and Development Outlook*. London: Eathscan.

Breton. F.; Clapés. J.; Marquès. A., and Priestley. G.K. 1996. The recreational use of beaches and consequences for the development of new trends in management: the case of the beaches of the Metropolitan Region of Barcelona (Catalonia.Spain). *Ocean & Coastal Management*. 32(3): 153-180. doi: 10.1016/S0964-5691(96)00032-4

Cifuentes, M. et al. 1999. *Capacidad de carga turística de las áreas de uso público del Monumento Nacional Guayabo, Costa Rica*. Turrialba: WWF. Retrieved from: http://awsassets.panda.org/downloads/wwfca_guayabo.pdf

De Ruyck, M.C., Soares, A.G., and McLachlan, A. 1997. Social Carrying Capacity as a Management Tool for Sandy Beaches. *Journal of Coastal Research*, 13 (3): 822-830.

EEA. 1999. *State and pressures of the marine and coastal Mediterranean environment*. Luxembourg: Office for Official Publications of the European Communities. Retrieved from: http://www.eea.europa.eu/publications/ENVSERIES05/#parent-fieldname-title.

Ergin. A.; Karaesmen. E.; Micallef. A. & Williams. A. T. 2004. A new methodology for evaluating coastal scenery: fuzzy logic systems. *Area*. 36 (4). 367-386. doi: 10.1111/j.0004-0894.2004.00238.x

Huamantico, M.A.; Revollo, N.V.; Delrieux, C.A.; Piccolo, M.C., and Perillo, G.M.E. 2016. Beach carrying capacity assessment through image processing tools for coastal management. *Ocean & Coastal Management*, 130: 138-147. doi: http://dx.doi.org/10.1016/j.ocecoaman.2016.06.010

Jiménez, J.A.; Osorio, A.; Marino-Tapia, I.; Davidson, M.; Medina, R.; Kroon, A.; Archetti, R.; Ciavola, P. and Aarnikhof, S.G.J. 2007. Beach recreation planning using video-derived coastal state indicators. *Coastal Engineering*, 54: 507-521. doi:10.1016/j.coastaleng.2007.01.012

Jurado, J. and Pérez, Y. 2014. Dinámicas de ocupación en playas urbanas de Tarragona: estabilidad metropolitana y estacionalidad turística. *CyTET Ciudad y Territorio: Estudios Territoriales*, Vol. XLVI, nº 181.

Kalisch, D. 2012. Relevance of crowding effects in a coastal National Park in Germany: results from a case study on Hamburger Hallig. *Journal of Coastal Conservation*, 16: 531-541. doi: 10.1007/s11852-012-0195-2

Lucrezi. S.; Saayman. M., and Merwe. P. 2016. An assessment tool for sandy beaches: A case study for integrating beach description. Human dimension and economic factors to identify priority management issues. *Ocean & Coastal Management*, 121:1-22. doi: http://dx.doi.org/10.1016/j.ocecoaman.2015.12.003

Pessoa, R.M.C.; Pereira, L.C.C; Sousa, R.C.; Magalhães, A., and da Costa, R.M. 2013. Recreational Carrying Capacity of an Amazon Macrotidal Beach During Vacation Periods. *Proceedings 12th International Coastal Symposium* (Plymouth, England), *Journal of Coastal Research*, Special Issue No. 65, pp.

Rajan, B.; Varghese, V.M.; Pradeepkumar, A.P. 2013. Beach Carrying Capacity Analysis for Sustainable Tourism Development in the South West Coast of India. *Environmental Research, Engineering and Management*, 1 (63): 67-73. doi: http://dx.doi.org/10.5755/j01.erem.63.1.2648

Rangel-Buitrago. N.; Correa. I.D.; Anfuso. G. Ergin. E. & Williams. A.T. 2013. Assessing and managing scenery of the Caribbean Coast of Colombia. *Tourism Management*, 35: 41-58. doi: 10.1016/j.tourman.2012.05.008

Ribeiro. M.F.; Ferreira. J.C., and Silva. C.P. 2011. The Sustainable Carrying Capacity as a Tool for Environmental Beach Management. *Journal of Coastal Research*. Special issue 64: 1411-1414.

Roca, E.; Riera, C.; Villares, M.; Fragell, R., and Junyent, R. 2008. A Combined Assessment of the Beach Occupancy and Public Perceptions of Beach Quality: A Case Study in the Costa Brava, Spain. *Ocean & Coastal Management*, 51: 839-846. doi:10.1016/j.ocecoaman.2008.08.005

Roca. E. and Villares. M. 2008. Public Perceptions for Evaluating Beach Quality in Urban and Semi-natural Environments. *Ocean & Coastal Management*, 51 : 314-329. doi:10.1016/j.ocecoaman.2007.09.001

Saveriades, A. 2000. Establishing the Social Tourism Carrying Capacity for the Tourist Resorts of the East Coast of the Republic of Cyprus. *Tourism Management*, 21: 147-156.doi: 10.1016/S0261-5177(99)00044-8

Silva, C. 2002. Beach Carrying Capacity Assessment: How Important is It? *Journal of Coastal Research*, Special Issue 36: 190-197.

Silva, C., Alves, F., and Rocha, R. 2007. The Management of Beach Carrying Capacity: The Case of Northern Portugal. *Journal of Coastal Research*, 50: 135-139.

Silva, S.F., and Ferreira, J.C. 2013. Beach Carrying Capacity: The Physical and Social Analysis at Costa de Caparica, Portugal. *Journal of Coastal Research*, Special Issue 65:1039-1044. doi: http://dx.doi.org/10.2112/SI65-176.1

Snowman, M.R. 1987. A Procedure for Assessing Recreational Carrying Capacity of Coastal Resort Areas. *Landscape and Urban Planning*, 14 (C): 331-344. doi: 10.1016/0169-2046(87)90044-2

Tripadvisor. 2016. Retrieved August 3, 2016 from https://www.tripadvisor.com

Williams. A.T.; Rangel-Buitrago. N.G.; Anfuso. G.; Cervantes. O. & Botero. C.M. 2016. Litter Impacts on Scenery and Tourism on the Colombian North Caribbean Coast. *Tourism Management*. 55. 209-224. doi: http://dx.doi.org/10.1016/j.tourman.2016.02.008

Williams, P.; Lemckert, C. 2007. Beach Carrying Capacity: Has it Been Exceeded on the Gold Coast? *Journal of Coastal Research*, Special issue 50: 21-24.

WTO. 1981. *Saturation of Tourist Destination: Report of the Secretary General*. Madrid: World Tourism Organization.

Yepes, V. 1999. Las playas de la gestión sostenible del litoral. *Cuadernos de Turismo*, 4: 89-110.

Zacarias, D.; Williams, A.T., and Newton, A. 2011. Recreation Carrying Capacity Estimations to Support Beach Management at Praia de Faro, Portugal. *Applied Geography*, 31: 1075-1081. doi:10.1016/j.apgeog.2011.01.020

Table 1. Number of beachgoers on Riumar beach in 5m strips from the shoreline.

	Strips from the shoreline (meters)																			
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
1st week June	3	27	23	16	25	14	16	17	10	3	4	-	2	-	-	3	-	-	-	-
2nd week June	-	-	12	3	2	-	1	1	-	-	1	2	3	-	-	-	-	-	-	-
3rd week June	1	17	23	12	5	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-
4th week June	1	17	23	12	5	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-
1st week July	12	28	20	12	2	-	-	4	1	-	-	-	1	2	5	-	-	-	-	-
2nd week July	2	16	6	8	6	12	12	8	4	3	-	-	3	5	2	6	-	-	5	-
3rd week July	34	119	46	17	12	19	16	6	13	3	1	5	2	-	1	-	-	-	1	1
4th week July	21	56	22	2	2	-	1	7	6	3	3	-	-	-	4	-	-	-	-	-
5th week July	21	56	22	2	2	-	1	7	6	3	3	-	-	-	4	-	-	-	-	-
1st week August	14	67	80	48	29	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2nd week August	9	60	79	47	29	8	7	2	-	-	-	-	-	-	-	-	-	-	-	-
3rd week August	15	70	97	69	42	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4th week August	1	39	68	70	31	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1st week September	3	8	8	4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2nd week September	4	8	8	6	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3rd week September	-	4	8	6	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4th week September	3	8	8	8	7	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Number of beach-goers on Muntanyans beach in 5m strips from the fourteen access points to the beach.

	Strips from access points (meters)					
	5	**10**	**15**	**20**	**25**	**30**
1st week June	-	-	1	3	7	30
2nd week June	-	-	-	-	-	9
3rd week June	-	-	-	3	6	3
4th week June	-	-	-	2	9	8
1st weekJuly	-	-	-	2	3	15
2nd weekJuly	-	-	4	1	2	-
3rd weekJuly	-	-	2	4	9	1
4th weekJuly	-	-	2	1	3	9
5th weekJuly	-	-	-	4	3	7
1st weekAugust	-	-	3	12	17	11
2nd weekAugust	-	-	-	-	18	30
3rd weekAugust	-	-	3	9	19	28
4th weekAugust	-	2	-	-	1	55
1st weekSeptember	-	-	-	1	-	6
2nd weekSeptember	-	-	-	-	-	-
3rd weekSeptember	-	-	1	7	13	-
4th weekSeptember	-	-	-	-	-	34

Table 3. First crowdedness sub-index analyzing 100m^2 plots on Trabucador beach and showing the availability of sand (m^2) per beachgoer when the beach is crowded.

	≤ 5.0 m^2/user	5.1-7.0 m^2/user	7.1-9.9 m^2/user	≥ 10.0 m^2/user
1st week June	2	0	0	145
2nd week June	3	0	0	174
3rd week June	5	3	4	86
4th week June	6	3	4	80
1st weekJuly	5	0	0	72
2nd weekJuly	10	0	0	152
3rd weekJuly	8	0	0	240
4th weekJuly	3	0	1	246
5th weekJuly	3	0	0	247
1st weekAugust	11	1	1	631
2nd weekAugust	22	3	4	641
3rd weekAugust	10	0	5	674
4th weekAugust	7	1	2	406
1st weekSetember	1	1	0	144
2nd weekSetember	1	1	0	34
3rd weekSetember	1	0	0	34
4th weekSetember	2	0	0	48

Table 4. Third crowdedness sub-index analyzing the whole of Muntanyans beach and showing the percentage of sand available when the beach is crowded.

	≤ 9.9 m^2/user	10.0-29.9 m^2/user	30.0-49.9 m^2/user	≥ 50.0 m^2/user
1st week June	0.00	0.00	0.00	0.12
2nd week June	0.00	0.00	0.00	0.07
3rd week June	0.00	0.00	0.17	0.00
4th week June	0.00	0.27	0.00	0.00
1st week July	0.00	0.00	0.08	0.00
2nd week July	0.00	0.26	0.00	0.00
3rd week July	0.30	0.00	0.00	0.00
4th week July	0.26	0.00	0.00	0.00
5th week July	0.05	0.00	0.00	0.00
1st week August	0.40	0.00	0.00	0.00
2nd week August	0.33	0.00	0.00	0.00
3rd week August	0.37	0.00	0.00	0.00
4th week August	0.42	0.00	0.00	0.00
1st week September	0.00	0.00	0.00	0.02
2nd week September	0.00	0.00	0.00	0.00
3rd week September	0.00	0.00	0.14	0.00
4th week September	0.00	0.00	0.00	0.05

Table 5. The CI scores and main data for the four beaches in the third week of August, the most crowded week on average.

	Muntanyans	Cala Fonda	Riumar	Trabucador
Number of users	291	46	302	690
Total number of $100m^2$ blocks	1689	85	2299	10120
Number of occupied $100m^2$ blocks	455	36	274	689
CI minimum score	0.7	2.4	1.3	1.0
CI maximum score	2.8	3.7	3.4	3.1
CI average	1.8	3.0	2.5	2.2

Figure 1. Graphic overview of the BCI procedure. Beachgoers are georeferenced (A); first sub-index is generated by overlaying a 10m*10m block grid (B); second sub-index obtains beachgoer data surrounding each $100m^2$ block (C); third sub-index obtains data for the entire beach and the total number of beachgoers (D).

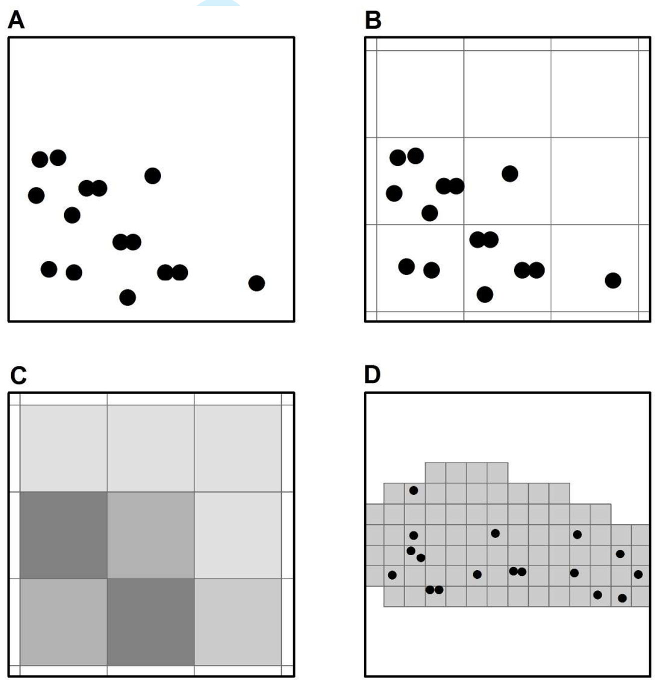

Figure 2. Location and panorama of the four beaches studied.

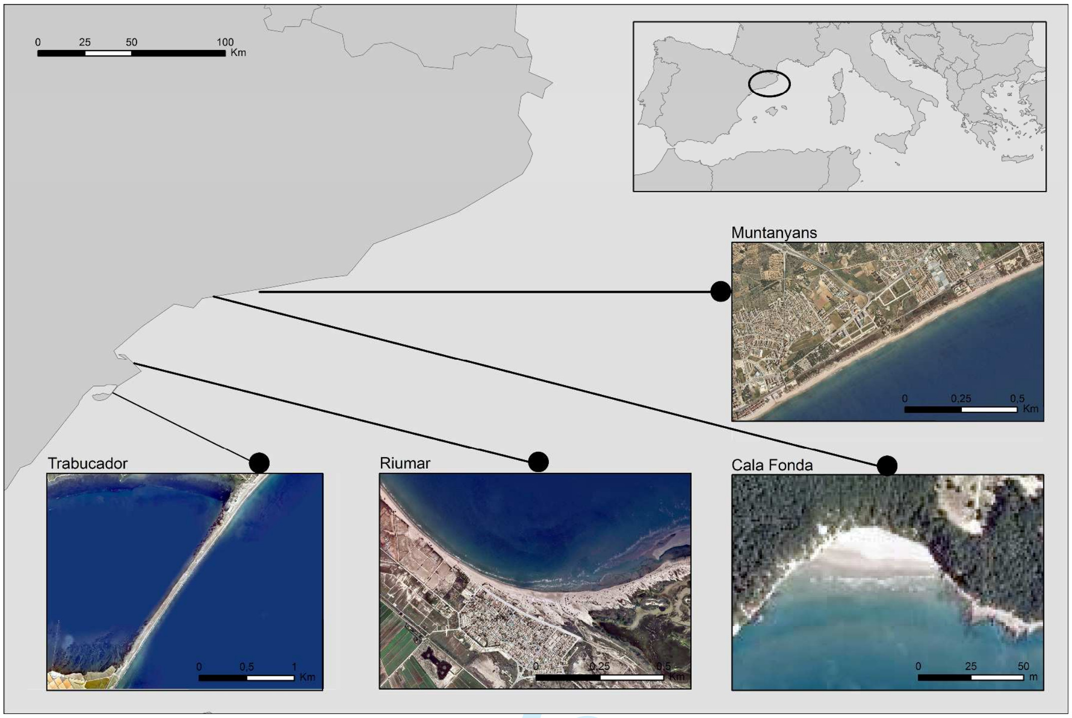

Figure 3. Number of people on the four beaches per week throughout the bathing season.

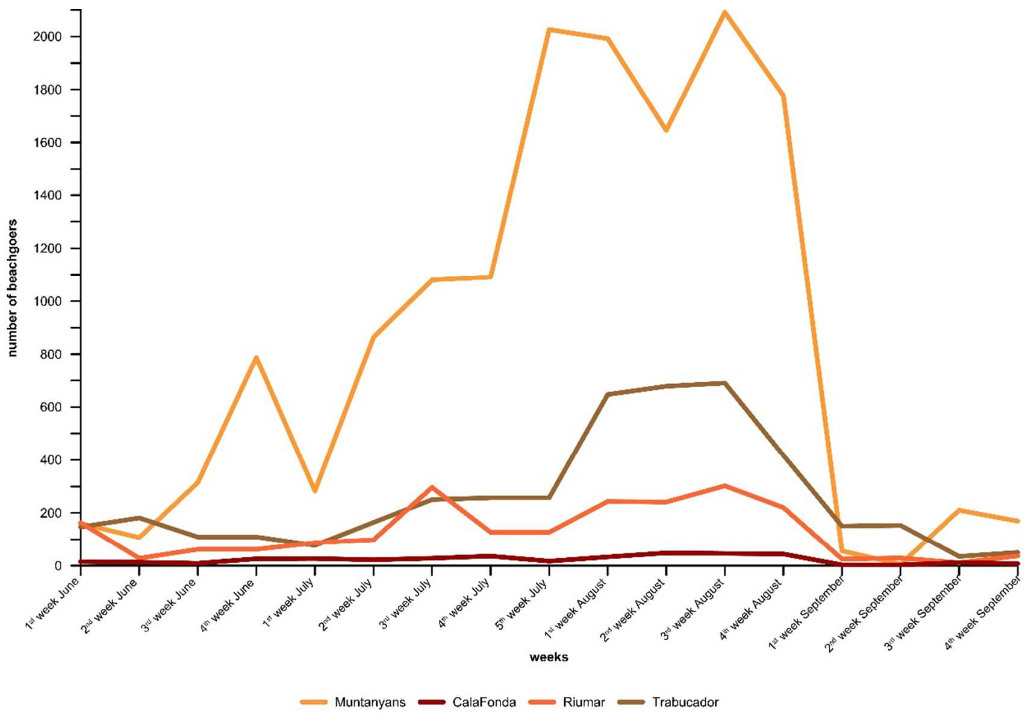

Figure 4. The BCI applied to Cala Fonda beach throughout the bath season.