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Beach carrying capacity assessment through image processing tools for coastal management

M. Andrea Huamantinco Cisneros [a, e, *], Natalia V. Revollo Sarmiento [a, b, c], Claudio A. Delrieux [c], M. Cintia Piccolo [a, e], Gerardo M.E. Perillo [a, d]

[a] Instituto Argentino de Oceanografía, CONICET, Florida, 8000, Bahía Blanca, Argentina
[b] Facultad de Ingeniería, UNJu, Gorriti 237, Jujuy, Argentina
[c] Instituto de Investigaciones en Ingeniería Eléctrica, CONICET and Dpto. de Ing. Eléctrica y de Computadoras, UNS, Av. Alem 1253, Bahía Blanca, Argentina
[d] Departamento de Geología, UNS, San Juan 670, Bahía Blanca, Argentina
[e] Departamento de Geografía y Turismo, UNS, 12 de Octubre y San Juan, Bahía Blanca, Argentina

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ABSTRACT

Coastal environments are spaces where people may develop varied economic and recreational activities, such as tourism, which usually damage beaches and other natural resources commonly placed in these settings. The aim of this paper is to present a methodology to estimate and evaluate the Beach Carrying Capacity (BCC) and the actual beach usage level in coastal cities, using on-site information and video processing to provide significant real-time data. To test our methodology, we chose the coastal city of Monte Hermoso, Argentina, as a pilot site because it is by far the prime choice for a large population during summer vacation in this country. Initially, to estimate BCC, cartographic information about facilities and beach zones was collected and combined with surveys requested to tourists, to better understand their habits and preferences. This allowed an accurate estimation of other beach capacities related to BCC. Secondly, beach video sequences were processed with an algorithm that identified, located and counted people on the beach with an adequate accuracy. The actual occupancy factor was computed and used to asses whether the BCC had been exceeded. Also, people were tracked and their preferred relaxing areas were registered (e.g, closer to seaside during the morning). Finally, all the information was stored and visualized using a Geographic Information System (GIS) which allows both to analyze the different information layers and to produce interactive thematic maps. In this way, the resulting methodology may help to identify zones under risk of deterioration and to define suitable places for the development of varied activities (specially those related to tourism). It may also serve as a dashboard for decision and policy making and contribute to coastal management planning as well.

1. Introduction

Since the 1950s, there has been a major change in the way that beaches have been used. Sun-and-beach tourism has become increasingly popular, triggering an exponential demographic development of seaside resorts and coastal cities. This population rise has generated major environmental changes, including forestation with foreign or invasive tree species, elimination of coastal dunes and installation of breakwater facilities for fishing and sailing, among others. All these anthropic interventions strongly modify the prior natural equilibrium: for example, the sand exchange among sea, beach and dunes results, in most cases, in unpredictable erosional situations (Perillo, 2003).

Beaches present a variety of functions and interests, such as recreation, tourism, conservation and coastal defense. For tourism and recreational activities, which include all kinds of outdoor activities like swimming, fishing, sailing, and sunbathing, beaches are the preferred destination for many vacationists, and the land around them becomes the placement for residential and hotel facilities, increasing all kinds of anthropic pollution. Without adequate planning and policy making, these factors may damage the environmental health and aesthetics of the beaches in an irreversible manner (Komar, 1976). A deep understanding of the population habits in coastal environments is a key factor to

* Corresponding author. Current address: CC804, B8000FWB, Bahía Blanca, Argentina.
E-mail address: mandreahc@criba.edu.ar (M.A. Huamantinco Cisneros).

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establish different types of policies regarding resource management, emergency response, and pollution control, among others (Osorio et al., 2012).

Beach overcrowding is mainly caused by the associated economic profit, and the related problems have motivated an international concern on the establishment of Coastal Management Plans (CMP). These plans allow to use coastal resources better and to protect beach environments against erosion, pollution and overexploitation of the resources.

CMPs are applicable to beach management, exhibiting a much more specific local approach to this kind of environments (Williams and Micallef, 2009). Beach Management (BM) focuses on CMP concepts in the local scale. BM seeks to maintain or improve beaches as a recreational resource, aiming to coastal protection while providing facilities that meet the needs and requirements of those who use the beach (Bird, 1996). Thus, in the elaboration of plans for BM, an accurate assessment of Beach Carrying Capacity (BCC) is essential (Jiménez et al., 2007; Silva et al., 2007; Quicoy and Briones, 2009; Ribeiro et al., 2011; Simeone et al., 2012; Rajan et al., 2013).

In Social Sciences, BCC enables estimations of the limits of economic and human activities that can be sustainable for the environment (Graefe et al., 1984; Shelby and Heberlein, 1984; Stankey and McCool, 1984). In tourism, BCC is an important indicator for natural environmental studies related to a specific human appraisal (Williams and Lemckert, 2006). BCC provides information about the ratio between the recreational use of the beach against satisfaction level of the users. As expected, when an inadequate use of the beach increases, the satisfaction degree decreases. The explosion of massive tourism in the last decades has motivated some studies of BCC that were essential to provide utilization indexes (Jurado et al., 2009; Tejada et al., 2009; Navarro Jurado et al., 2012; Wei et al., 2014).

BCC is defined as the relation between the available surface and the beach occupation level. However, there are several factors that exert additional influences on an accurate BCC assessment, such as urban and environmental characteristics of the surroundings, specific geographic and geomorphologic features of the beach, and other external factors (Pereira da Silva, 2002).

Another approach considers three levels of carrying capacity: physical carrying capacity (PCC), real carrying capacity (RCC) and the effective or permissible carrying capacity (ECC) (Cifuentes, 1992; Cifuentes et al., 1999; Sayan and Atik, 2011). PCC is the control factor, whereas RCC and ECC represent levels that consider different internal and external factors. On the other hand, diverse indicator variables have been considered to obtain a better comprehension of the different carrying capacity types (De Ruyck et al., 1997; Jiménez et al., 2007; Manning, 2007; Tejada et al., 2009; Silva et al., 2011; Navarro Jurado et al., 2012; Rajan et al., 2013).

BCC has been applied to different management projects around the world. Echamendi Lorente (2001) oriented their BCC research to contribute conceptually and methodologically for future studies. A different approach in the study of tourist sustainability in the Chilean coast employed the BCC of a natural environment to identify a theoretical daily capacity resulting in beach overuse (Portal Valenzuela, 2008).

In the Dominican Republic, BCC of Playa Grande was studied in well-defined zones in order to understand the effects of anthropic pressure on this coastal city (Betancourt-Fernández and Herrera-Moreno, 2005). Their results are considered as a preliminary contribution for the development of environmental impact investigations. Research in Tamandaré Beach (Brazil) calculated the BCC of two areas: the beach zone and the natural pools in order to analyze the natural resource sustainability. The results showed that even though the number of visitors did not surpass the carrying capacity limits, tourists' damaging behavior threatened the beach resource stability (Dias e Cordeiro et al., 2013).

In Argentina, there are few studies about BCC from the perspective of touristic activities. Recent studies; in this regard, of the northern Patagonian coast were oriented towards the analysis of the present situation, to better understand the factors involved in its evolution through the BCC concept (Camino et al., 2007). The results of this research showed that some beaches receive twice the recommended BCC, whereas others are close to their limit.

The aim of the research presented here is to develop a methodology to estimate BCC and evaluate the actual beach usage level in coastal cities through the use of information about facilities and beach zones, combined with surveys and video processing. The actual beach utilization level was used to assess BCC in Monte Hermoso city, Argentina, which was chosen as a pilot site for an initial deploy of the methodology (Fig. 1). The information was correlated with the estimated BCC and integrated into a GIS, which allowed to store, analyze and manage all the relevant information. Furthermore, we proposed new assessment approaches for the key indicators that may be used by decision makers, lifeguards and security services, to be applied in defining policies regarding the use of space, and in emergency and contingency planning. The results of the experience were promising and, currently, the whole experience is planned to be replicated in other coastal cities along the Argentine coastline.

2. Methodology

2.1. BCC estimation

The methodology developed by Cifuentes (1992) and Cifuentes et al. (1999) was used as a framework to estimate physico-ecological factors concerning the carrying capacities in Monte Hermoso beach. This framework estimates the maximum number of people that an area can support, considering its physical, biological and management conditions. As mentioned above, three levels of carrying capacity are defined: physical carrying capacity (PCC), real carrying capacity (RCC) and effective or permissible carrying capacity (ECC). PCC considers the maximum limit of visitors in a space during a specific time. RCC is the maximum permissible limit of visits, considering correction factors based on the particular features of the beach applied to PCC. ECC represents the maximum number of visitors that the site can support, based on RCC and the management capacity (MC) of the site. A wide range of information (number of people, areas, meteorological data, *in situ* beach measurements, etc.) is required to estimate the physico-ecological factors influencing the carrying capacities. External factors such as accommodation, parking places, vehicle entrances, fishing activities, dune and rock zones have to be considered as well (Pereira da Silva, 2002). Determination of the PCC is made by

$$\mathrm{PCC} = \frac{A}{A_U} * T_f, \tag{1}$$

where A is the size of the study area, A_u represents the area available (occupancy criteria), and T_f is the number of times that a person may visit the area in a day (the relation among the visitation schedule and the time required for each visit). A, in fact, may vary widely according to tidal conditions. In the study reported here we considered the worst case scenario, *i.e.*, area in high tide. The occupancy criteria are based on the model established by Norma-Cubana (1988) (Fig. 2), which considers three possible situations: high, medium and low occupancy with a space for each visitor of 5, 10 and 25 m^2, respectively. Then, the value T_f is obtained through an

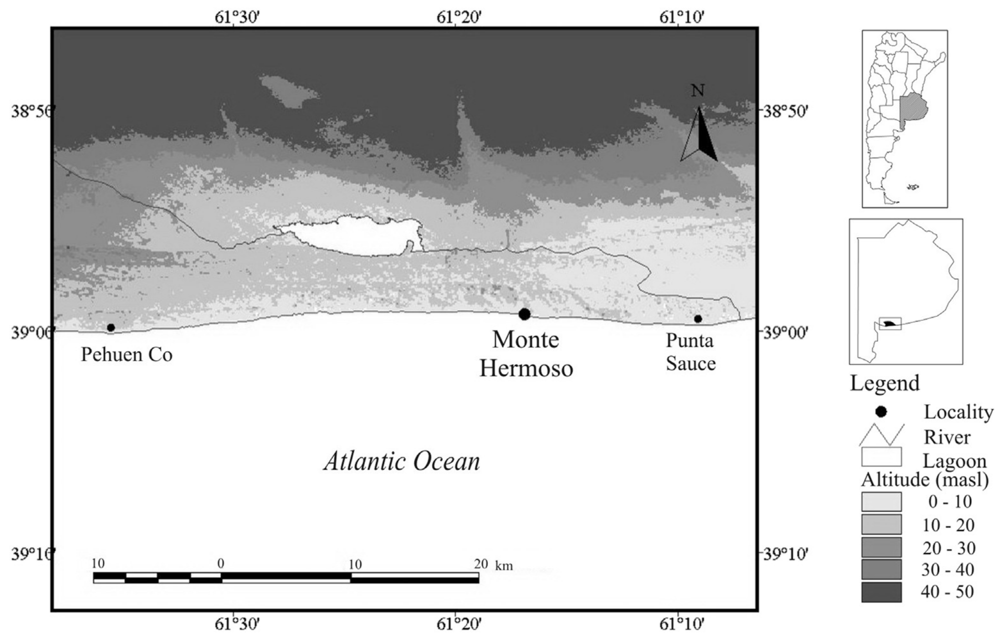

Fig. 1. Location of the study area, Monte Hermoso city (Buenos Aires Province, Argentina).

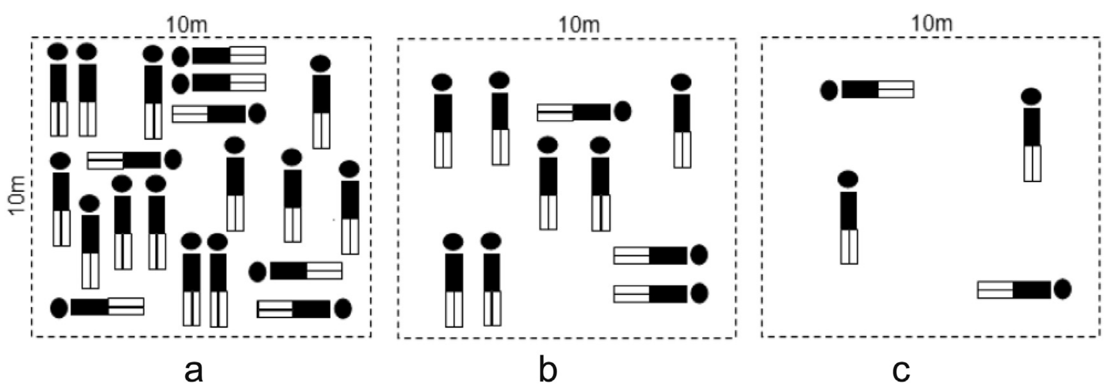

Fig. 2. Occupancy condition criteria (in m^2 per occupant): a) 20 people/100 m^2, b) 10 people/100 m^2 and c) 4 people/100 m^2, which corresponds to an area of, 5, 10 and 25 m^2 per user, respectively.

estimation of a sequence of questionnaires collected in the study zone (Huamantinco Cisneros, 2012).

$$\mathrm{RCC} = \mathrm{PCC} * \frac{100 - Cf_1}{100} * \frac{100 - Cf_2}{100} * \frac{100 - Cf_3}{100} * \cdots * \frac{100 - Cf_n}{100}, \tag{2}$$

$$Cf_i = \frac{Ml_i}{Mt_i} * 100, \tag{3}$$

In Eq. (2), RCC is defined in terms of PCC and several external factors, where Cf_i are the correction coefficients for each generic factor i considered. All the Cf_i factors are expressed as percentages using Eq. (3), where Ml_i represents a measured value for each generic factor i, and Mt_i is its maximum allowable value. Factors include rainfall, strong winds, sunshine, temporary closure periods, and beach erosion (Zacarias et al., 2011). These factors were chosen because of their influence in recreational activities (Cifuentes, 1992; Cifuentes et al., 1999).

To understand the specific importance of these factors and their allowable values, information was gathered from random polls to visitors, historic files, the Argentinian National Meteorological Service, Monte Hermoso city archives, and studies performed at the Instituto Argentino de Oceanografía. Rain and strong winds prevent people from going to the beach for recreation. Sunshine and temporary closure were also considered because they limit the feasible times to visit the beach. Finally, erosion was also included as a limiting factor, given the importance of beach erosion in the reduction of the available recreation space.

$$\mathrm{ECC} = \mathrm{RCC} * \frac{\mathrm{MC}}{100}. \tag{4}$$

Equation (4) shows the ECC definition, where MC is the management capacity of the zone under consideration. For the estimation of the MC, the factors considered were: institutional support (information services, coastal management plans, building regulation, access regulation), services (tent rental, restaurants, drugstores), personnel (lifeguards, people trained for natural disaster response) and infrastructure (bathrooms, public lighting, coastal buildings, street/beach signaling, beach access, recreative areas, police/coastguard and fire stations, vehicles and means for assistance in natural disasters). Qualitative information such as beach accesses, accommodation, recreational and parking places, fishing, dune and rock zones had to be included as well (see Tables 1 and 2).

Regarding socio-cultural factors with influence on carrying capacities, to know the tourists' profile and their preferences, 201 questionnaires were completed during the summer (high season), in January and February, 2011. The questionnaires focused on different aspects such as categorizing the visitor group (family, single, etc.), education level, age, frequency of visits to the coastal city, hours spent on the beach, activities developed by the group, visitor' cities of origin, and visitor' satisfaction with the place, among others.

2.2. Real-time counting of beach users

An unsupervised algorithm was developed for counting and locating people on the beach (Revollo Sarmiento, 2012), based on image reprojection and prototype-based classification. The designed algorithm operated directly on the output stream of an off-the-shelf inexpensive video camera, either in MPEG or in H264 formats, and ran in low-cost tiny embedded systems like the `Raspberry-Pi`.[1] In this way, very small autonomous monitoring stations were built, which performed people counting and locating and periodically transmitted the data to a server over the GPRS network. The software was developed using only open-source royalty-free software (Linux operating system, GCC compiler, and OpenCV libraries). Thus, the cost of the required hardware and software was low enough to make the construction affordable, allowing to deploy several monitoring stations across a coastal town.

The software received the video stream and averaged a given amount of frames every ten seconds (typically six frames, depending on the computational power of the embedded system). Averaging frames is a well-known technique that reduces the amount of noise significantly; performing the count and location every ten seconds was more than enough for our purposes. Each mean frame was reprojected to a zenithal view, which required a calibration step that needed to be performed only once. The input parameters for a standard 4-point reprojection formula were obtained by marking four points on the beach that delimited the region of interest (ROI), registering their geographical location using a differential GPS, and simultaneously marking the position of these points in the frame buffer of the camera (Szeliski, 2010) (Fig. 3). In the reprojected frames, there was a direct correspondence between the (x,y) pixel positions in the frame and the $(lat,long)$ geographical coordinates.

A pattern recognition procedure based on prototype classification was run within the ROI, which delivered the positions where people were located (hits, or true positives). Basically, the procedure classified pixels into two classes, human and non-human. During training, the classes were described by a feature vector (or prototype) obtained in YIQ color space and distinguished from prototypes of typical beach zones with the aid of an expert in coastal zones (including dry zone, wet zone, water, shadow area). Once prototypes were defined for each one, the Euclid distance in YIQ color space between every pixel and a prototype k could be computed for every pixel in the averaged frames:

$$d_{kp} = \sqrt{(Y_p - Y_k)^2 + (I_p - I_k)^2 + (Q_p - Q_k)^2}, \tag{5}$$

where (Y_k, I_k, Q_k) are the color prototypes of class k, and (Y_p, I_p, Q_p) are the YIQ components of the pixel. Each pixel was classified so as to belong to the class with the least d_{kp}. These steps are illustrated in Fig. 4. The procedure was trained with a set of examples, and the working parameters were tuned to compensate the number of losses (false negatives, *i.e.*, undetected humans) with false alarms (false positives, *i.e.*, objects erroneously classified as humans). In this way, the accumulative error tended to zero in the long run (Fig. 5). As a by-product, it was possible to track the beach users' behavior and movements to gain some insights on their particular trends and drives.

Table 1
Classification of BCC qualitative variables: Beach facilities.

Qualitative variable	High (H)	Medium (M)	Low (L)
Beach access	H (>4)	M (between 2 and 4)	L (1)
Accommodation	H (>10)	M (between 4 and 10)	L (<4)
Recreation places	H (≥4)	M (between 2 and 4)	L (<2)
Parking places	H (>500)	M (between 100 and 500)	L (<100)

Table 2
Classification of BCC qualitative variables: Special Zones.

Qualitative variable	
Fishing zone	Yes/No
Dune zone	Yes/No
Rocks zone	Yes/No

3. Results and discussion

In this section, we show how we applied the proposed methodology in Monte Hermoso, Argentina. Initially, six different zones on the beach were identified and defined according to their uses (Fig. 6). The measurements of each zone to calculate physical and ecological carrying capacity are shown in Table 3.

The beach zones were defined as follows:

Zone 1: Limited by A (vehicular entrance) to B (fishing boat entrance). This zone presented frontal dunes vegetated with tamarisk, and its seaside area had rocky outcrops. There was scarce tourist influx, but some fishing activities were likely to arise (artisanal and/or sport).

Zone 2: Located from B to C. In this zone the presence of tourists began to increase. The residential area was more crowded, and there were streets with direct access to the beach. For this reason, specially in summer, the beach received a moderate influx of both tourists and residents.

Zone 3: Defined between C and D. This area was the most densely urbanized and received the highest influx of tourists. It had recreational venues and hotels, which further increased the number of tourists on the beach. Fishing activities during summer were not allowed.

Zone 4: Located from D to E (the eastern limit of Monte Hermoso city). It was near downtown and influenced by the urban residential area. Together with Zone 3, this area concentrated the most crowded accesses to the beach. In both zones (3 and 4) vehicle circulation was restricted throughout the whole year.

Zone 5: It extended from E to F (the western limit of Faro Recalada Village). This zone had a low influx of tourists, although fishermen were always present. Also, this area had a special access for boats and other similar water vehicles.

[1] https://www.raspberrypi.org.

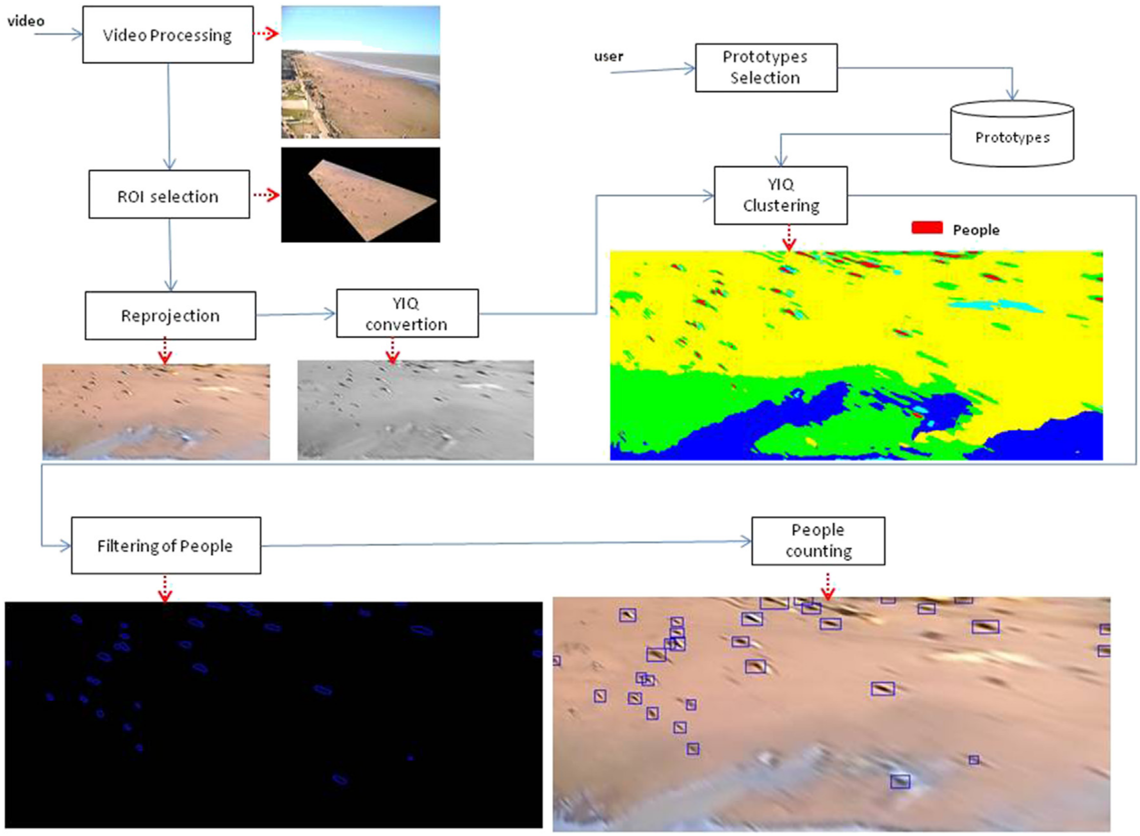

Fig. 3. (Left) Oblique view of zone 4 taken with the monitoring station. (Right) ROI selection for people counting. This image was taken on February 26, 2010.

Fig. 4. Software diagram for people recognition and counting. Red color represents people class during the segmentation. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Zone 6: From Faro Recalada Village to the Lighthouse with the same name. There were less tourists (in this area) than in zones 2 to 5. Recreational activities related to fishing and sports (windsurfing and kitesurf, among others) were common. There were altogether 59 accommodations places, 42 beach accesses and 31 parking lots (Fig. 7). In addition, we carried out a qualitative description of external factors and special zones. The special zones included fishing spaces, dunes and rocks. The qualitative information was added in the GIS (Fig. 6).

The analyzed external factors concerning the evaluation of BCC, ECC and PCC showed that there were 59 rainy days per year, and 170 days per year with strong winds. Therefore, the correction percentages for these factors were 16 and 47%, respectively. There were about 5110 sun hours per year (yielding a 41% for the corresponding correction factor), and the beach was not accessible for 170 days per year (correction factor 61%). Finally, Monte Hermoso beach lost about 42,000 m^3/year of sediment, which reduces the total area of the beach in about 12,000 m^2/year, generating an erosion correction percentage of 14% (Huamantinco Cisneros, 2012).

Zones 3 and 4 concentrated the most important services, such as shops, hotels and parking spaces, including the highest concentration of accesses to the beach. Moving away from downtown (zones 1, 2, 5 and 6), service availability decreased, which is

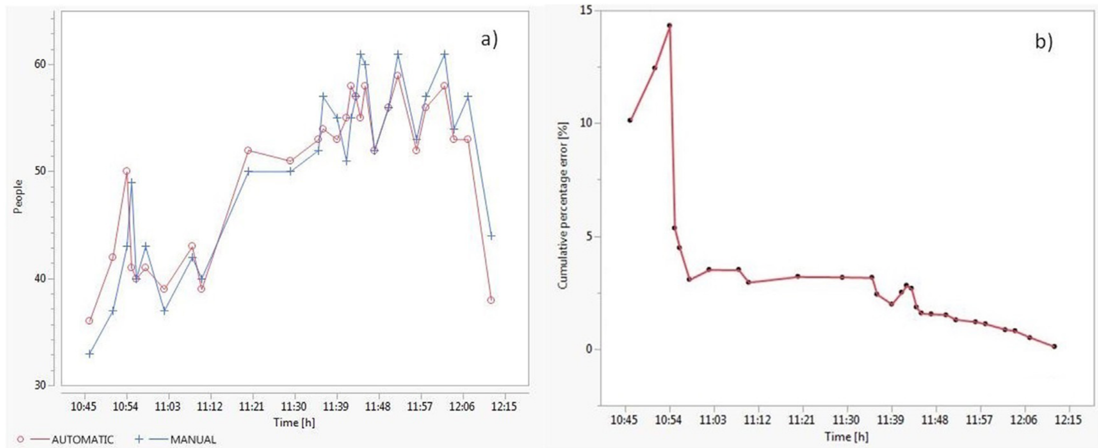

Fig. 5. (a) Supervised and unsupervised people counting in February 26, 2010 in the study area. (b) Cumulative percentage error of the unsupervised algorithm. The number of false positives and false negatives tend to cancel each other and, in the long run, the misclassifications are negligible.

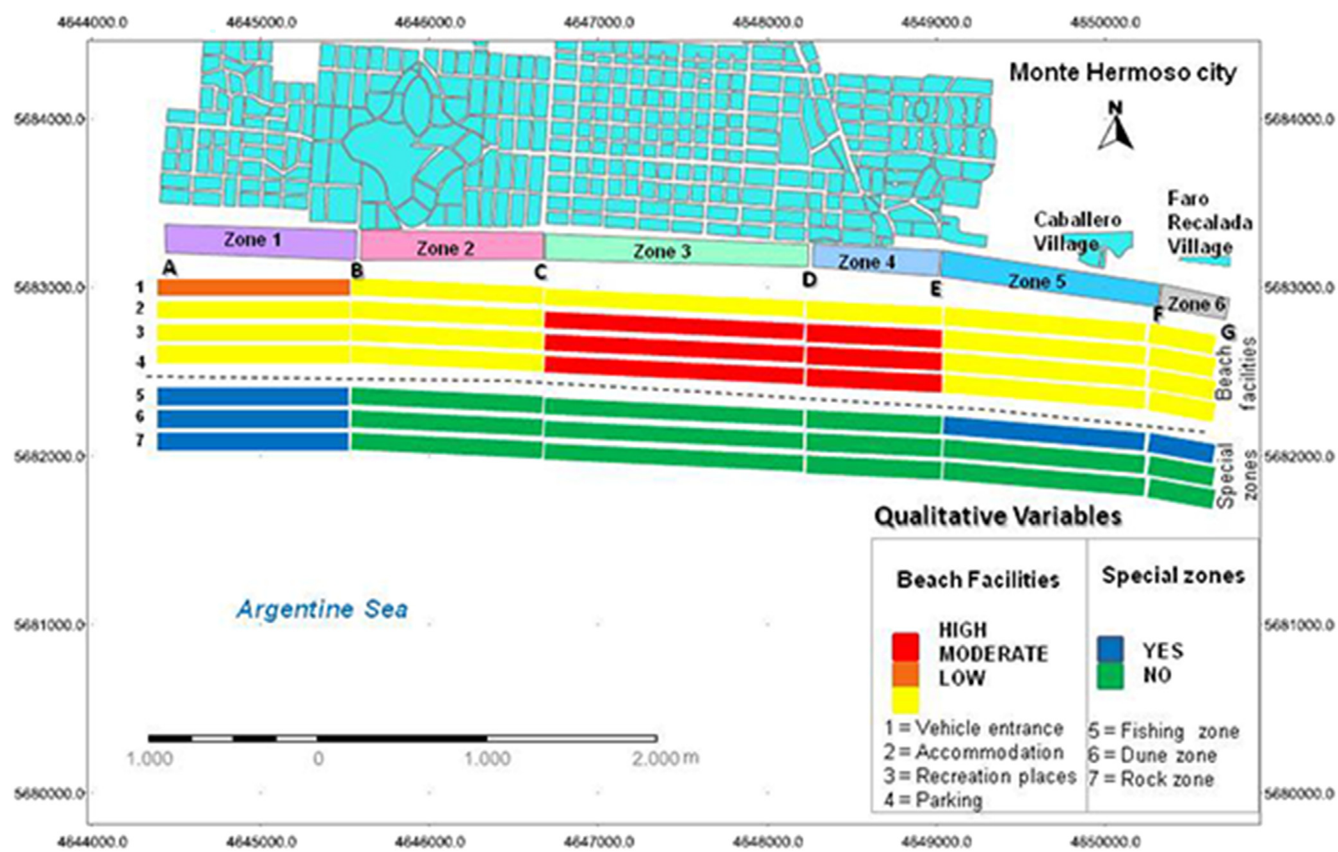

Fig. 6. Beach zones in Monte Hermoso city and the situation of the qualitative variables considered.

Table 3
Planimetric area of each beach zone defined.

Zone	Area (m^2)
Zone 1	194,665
Zone 2	186,116
Zone 3	229,800
Zone 4	111,856
Zone 5	190,923
Zone 6	54,560
Total	967,920

correlated with a lower number of users. As regards fishing activities, they were normally more active in zones 1, 5 and 6, corresponding to the coastal city limits, whereas in the downtown beach area it was not allowed during summer. The information presented was validated through visual observation using Google Earth imagery for summertime. The beach carrying capacity considered the items shown in Table 4. Results showed that Monte Hermoso actually had a MC mean value of 0.54 in all the six zones, including facilities, equipment, human resources and institutional support.

PCC, RCC and ECC were calculated considering the three

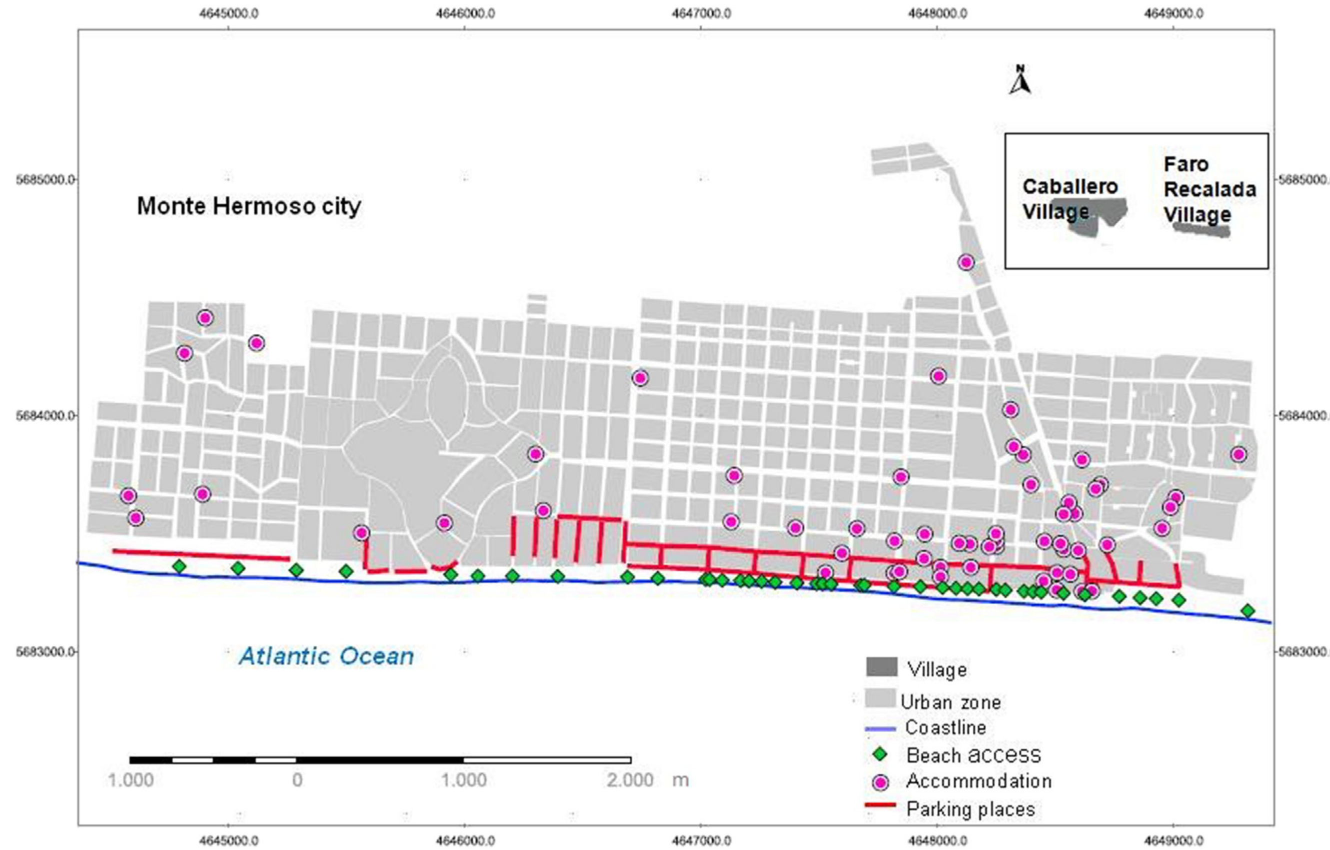

Fig. 7. Spatial distribution map of quantitative external factors corresponding to parking place, accommodation and vehicle entrance considered for Monte Hermoso city.

Table 4
Variables considered for MC estimation of Monte Hermoso city. 1: Lifeguard. 2: Bathrooms. 3: Public lighting. 4: Information services. 5: Coastal Buildings. 6: Tent rental. 7: Street/beach signaling. 8: Beach Access. 9: Wastebaskets. 10: Restaurants, drugstores. 11: Recreative areas. 12: Coastal management plans. 13: Building regulations. 14: Access regulations. 15: First aid. 16: Police and fire stations. 17: People trained for natural disaster response. 18: Vehicles and means to assist in natural disasters.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Zone 1						X	X	X			X					X		
Zone 2	X	X		X	X	X	X	X	X	X	X							
Zone 3	X	X	X	X	X	X	X	X	X	X	X			X	X	X		
Zone 4	X	X	X	X	X	X	X	X	X	X	X			X	X	X		
Zone 5					X	X	X	X		X	X			X		X		
Zone 6						X		X			X			X		X	X	X

occupancy criteria mentioned initially, after obtaining the area value of each zone, external factors, special zones and capacity management of the city. The six considered zones comprised a planimetric area of 967,920 m^2. The computed PCC value was 774,336, 387,168, and 154,867 visits per day corresponding to high, medium, and low occupancy conditions and considering a rotation factor of 4 (Ariza Solé, 2007). For good management, people counting should not exceed these values. RCC corresponded to 48,345, 24,172, and 9669 visits per day for each occupancy condition. These values indicated the maximum number of visitors, considering the correction factors. Finally, the ECC was calculated with information from the MC, yielding a value of 26,106, 13,053 and 5221 visits/day, respectively. The latter values represented the allowable number of people on the beach with the conditions given

Table 5
PCC, RCC and ECC for Beach Carrying Capacity management.

Occupancy	PCC			RCC			ECC		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Zone1	31,146	77,866	155,732	1944	4861	9723	1050	2625	5250
Zone2	29,778	74,446	148,892	1859	4648	9296	1003	2509	5019
Zone3	36,768	91,920	183,840	2295	5738	11,477	1239	3099	6198
Zone4	17,896	44,742	89,484	1117	2793	5586	603	1508	3016
Zone5	30,547	76,369	152,738	1907	4768	9536	1029	2574	5149
Zone6	8729	21,824	43,648	545	1362	2725	294	735	1471

Fig. 8. Location of the video monitoring station on top of a 30 m high building.

by the facilities, regulation compliance and available personnel (Table 5).

Results corresponding to socio-cultural factors influencing the carrying capacities showed that Monte Hermoso had a definite touristic profile during summer, characterized mostly by families and groups of friends. Most visitors preferred this coastal city for vacation because of the low crime rates. The most frequent age groups ranged between 25–34 and 55–64 (nearly 20% in both cases). The predominant familiar group consisted of couples (56.2%), followed by singles (31.3%) and other marital status groups (widow/er, divorced or cohabiter) (12.5%).

Families and other social groups spent there about 1 or 2 weeks. Other tourists visited the city as a day trip because it is closed to their place of residence. Visitors came mostly from the Buenos Aires Province (72.6%) and, to a lesser extent, from more distant provinces (over 1000 km away), such as Neuquén, Córdoba, Chaco and Santiago del Estero. More than half of the surveyed people said they had usually returned every year, whereas others did it for the first time. Tourists preferred to stay on the beach in the afternoon until 10 p.m.; others left the beach earlier at around 5 p.m.

Apart from the beach, during their stay tourists liked to visit the city center, the lighthouse, and the Sauce Grande lagoon, among other interesting places. The most noticeable situation was the low percentage of visits to the ancient (ca. 6500 yrs BP) human footprints, given that this is a remarkable interest site of the city. This fact might be related to the poor advertising about this place and the distance from downtown. Almost 50% of the survey respondents gave Monte Hermoso a grading of 8/10 points. Finally, 93% stated that they would likely return next year.

As regards people counting, a monitoring station was placed at a fixed position on top of a 30 m high building (46 m.a.s.l) (Fig. 8). The field of view covered a selected area having a panoramic view of zone 4.

Zone 4 was considered an example of people identification and counting, and estimation of BCC. From early in the morning until midday, an increase of the number of users in the analyzed sector was observed. In the first measurement, around 16 users were counted on the beach. This number increased until the end of the recording, with 54 visitors in the defined sector. This increase was coincident with temperature rise and better weather conditions to stay on the beach and perform beach activities. In addition, the

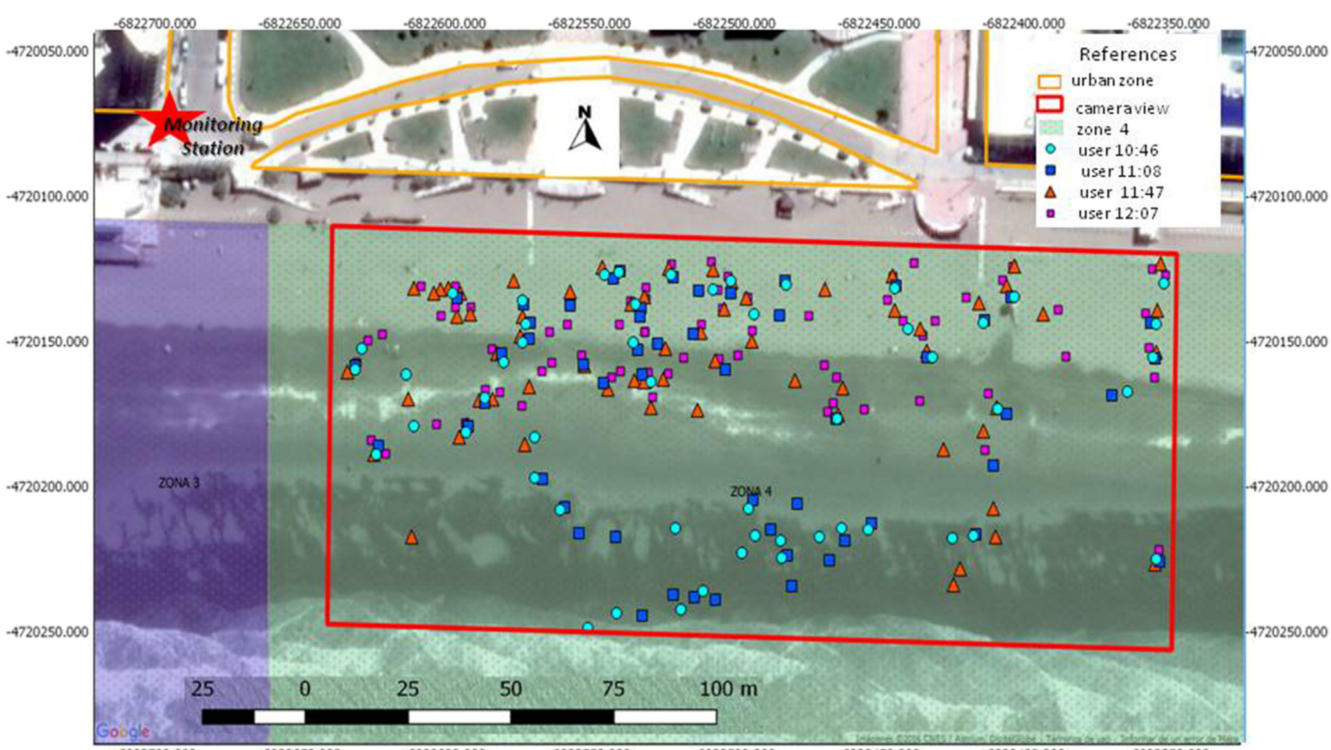

Fig. 9. GIS representation of users detected in an automatic way in the study area defined in Monte Hermoso. This image presents the situation on February 26, 2010 (summer in the Southern Hemisphere) near low tide hours.

movement of users at different moments of the datum acquisition was registered. In the early hours, people preferred to be nearer the waterline. Later, users moved near the boardwalk looking for shade to protect themselves from high temperatures. In Fig. 9, we illustrate how all this information may be rendered using a GIS as a dashboard. Considering the PCC, RCC and ECC for the different scenarios in zone 4 against the number of people detected with our methodology of counting users, the results showed that the BCC had not been exceeded for the sequences of the analyzed images. Interested readers may browse the companion website qgiscloud.com/Nrevollo/BeachCarryingCapacityGIS where all the information collected in this paper is presented.

4. Conclusions and further work

We present an integral methodology to estimate the Beach Carrying Capacity (BCC) and the actual beach usage level in coastal cities. The methodology considers an assessment of occupation conditions, weighted by a set of factors including environmental, urban, weather, and other constraints on the allowable number of beach users. Information is gathered using on-site measurements, interviews with users, historical data and scientific studies. To provide significant real-time data about actual beach users, an inexpensive monitoring station was designed, based on a low cost surveillance camera and an embedded system. A video analysis software was developed to identify and locate users in a region of interest within the camera view. The monitoring stations for video analysis allow also a deeper understanding of beach users' behavior along time. Finally, all the gathered data is presented on a GIS application.

The methodology was tested in Monte Hermoso City, Argentina, which receives a large influx of visitors during the summer vacation. We noticed that in zone 4 (area covered by the camera view) the BCC values were higher than the number of people estimated by the sequence of images analyzed. We also observed that people preferred to stay near shadow areas before midday because visitors felt more comfortable there.

The system developed is very simple, requires minimum investment and can be set up in a short time. Any video monitoring system already in place (i.e., monitoring cameras) can be used as long as the calibration is correct, and there are no changes in the zoom or direction. The software was made integrally with open source programs which are readily accessible to any interested party. Both concepts make the system adequately suitable for massive use, even in low-budget research projects or for authorities requiring long-term monitoring of beach processes.

The presented methodology can be easily adapted to other contexts and situations, including countries where different research projects are aiming at beach user estimation (for example ARGUS[2] and HORUS[3]). There are no regulations in Argentina that limits the use of CCTV systems in public places for research and governmental purposes. In other countries where a privacy breach can be claimed, an audit trail of the system can easily show that the information may never be used for people identification, given that single frames never persist. Only an averaging of frames (which blurs finer details) is used for counting; this fact, together with the standard webcam resolutions and aiming at very long distances, makes it absolutely impossible to identify people.

As far as we are concerned, this is the first attempt to integrate a diverse set of information sources aiming to provide real-time indicators that may serve as a dashboard for policy-makers and management planners. We are currently assembling several monitoring stations to provide a denser and wider coverage of the beach zone in Monte Hermoso. The data loggers of the stations will be periodically read by a client-server application that will fuse together the information in the GIS application. They will also allow access through web browsers and mobile applications so that stakeholders and general public might get real time information about the beach status. More sophisticated video analytic features, such as tracking individual users' trajectories for data analysis, are also under development.

[2] www.planetargus.com/.

[3] www.ihcantabria.com/en/recursos/item/293-horus.

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