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Rip currents signaling and users behaviour at an overcrowded urban beach

Jacqueline S. Silva-Cavalcanti[a,b,*], Monica F. Costa[b], Pedro S. Pereira[c]

[a] Universidade Federal Rural de Pernambuco – Unidade Acadêmica do Cabo de Santo Agostinho, BR 101 Sul, Cabo de Santo Agostinho, Pernambuco, Brazil
[b] Lab. Ecology and Management of Estuarine and Coastal Ecosystems, Departamento de Oceanografia, Universidade Federal de Pernambuco, Av. Arquitetura s/n, Recife, Pernambuco, Brazil
[c] Geological Oceanography Lab., Departamento de Oceanografia, Universidade Federal de Pernambuco, Av. Arquitetura s/n, Recife, Pernambuco, Brazil

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ABSTRACT

The spatial distribution and behavior of beach users, was studied in relation to rip currents signaling in 2004 and 2015. Overcrowded areas were classified according to the presence or absence of rip currents (RC) and red warning flags (RF). Images from an Argus video system and official drowning records were also analyzed to identify the most likely pattern of drowning and its relation to dangerous bathing conditions. The use of beach decreased when comparing 2004 and 2015 (40–67% in overcrowded areas). The annual drowning cases average (n = 402) was 67 ± 7 per year, of which ~5% resulted in fatalities. Drowning cases during weekends accounted for 60% of all records for the period. Overcrowded areas had the highest drowning records and fatalities. Images suggested that beach users choose to swim between the red warning flags. About 50% of the time, flags are in different places of those that denote risk, or permanent danger. The video images helped understand behavior of beach users concerning their choice of bathing area. Based on our study, we propose the video monitoring of the beach is continued and expanded. Therefore, the most critical areas of users safety can be identified. Also, clear, updated and well-distributed signaling of environmental assets and risks must be deployed. The collection and management of information about the beach, will greatly help in decision making and improvement of public environmental literacy, improving beach users recreational experience at urban crowded beaches by improving safety at different aspects.

1. Introduction

Urban beaches have a vocation for recreational use. Tropical climates favor the use of beaches all year round (Araújo and Costa, 2008), often leading to overcrowded and difficult to control situations (Stokes et al., 2017; Cervantes et al., 2015). However, even though some users expectations are met in terms of social experience, it is necessary that the beach also present adequate resources to increase their safety, including clear signs of rip current presence and risks (Bordehore et al., 2016; Williams and Micallef, 2009; Morgan et al., 2008; Jiménez et al., 2007).

Rips are narrow, often strong, seaward-flowing currents that represent a significant hazard to beach users around the world (Short and Hogan, 1994; Short, 1999; Williams and Micallef, 2009; Brighton et al., 2013; Arozarena et al., 2015), being capable of transporting even experienced swimmers to significant offshore distance, these currents are particularly threatening to children, as well as inexperienced and misinformed beach users (Arozarena et al., 2015). Occurring in many types of beach (Maia et al., 2014; Morrongiello et al., 2016) and being mobile along the shore and seasons, these are one of the main natural causes of drowning events (Klein et al., 2003). Rip currents are responsible for the immediate circulation next to the beach, the bathing area, and therefore swimmers may be caught and become susceptible to panic, physical exhaustion and drowning (Sherker et al., 2010).

Recife City's urban beaches are an important democratic space of leisure and contact with natural environments for the local population, day visitors and tourists (Costa et al., 2008). A Pernambuco State law (21.402; 6th May 1999) prohibited several water-related activities due to the risk of shark attacks (Chapman and McPhee, 2016). Some actions are the prohibition of swimming (especially at high tide; dusk and in winter months), aquatic sports (surf, bodyboarding etc.) and clear signs informing of shark attacks. Until then, little information about coastal morphology and rip currents existed for the area. Along Boa Viagem beach rip currents form along reef gaps and in places were topography gradients are present (Maia et al., 2014). Thirteen rip currents occur, nine permanent and four indicators of transversal circulation. Beachrocks contribute for the presence of permanent rip currents along the area (Maia et al., 2014).

* Corresponding author. Lab. Ecology and Management of Estuarine and Coastal Ecosystems, Departamento de Oceanografia, Universidade Federal de Pernambuco, Av. Arquitetura s/n, Recife, Pernambuco, Brazil.
E-mail address: jacque_ss@hotmail.com (J.S. Silva-Cavalcanti).

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Before 2013, no measure was taken to clearly signal the presence and position of rips and contribute to the security of the beach users. At present, rip currents are signaled daily, through the deployment of one, ideally two, red warning flags with the wording “PERIGO” – “danger” in Portuguese.

Nevertheless, despite shark attacks and rip currents, these areas continue being intensely used, including for sea bathing, without any scientifically established knowledge about the efficiency of such flags as indicators of danger in the area. To improve beach safety, it is essential to understand both beach natural dynamics and users perceptions and resulting behavior. Regarding the natural dynamics, aspects as water depth, surf zone topography, wave height and currents in the surf/bathing zone (ex. rip currents) (Short and Hogan, 1994; Klein et al., 2003), as well as hazards such as reefs and rocks (Short and Hogan, 1994) are all important in mapping possibilities of sensible beach use. The identification of spatio-temporal patterns of beach use and its variations based on studied users preferences can also help in evaluating risk factors on the beach.

Risk is the sum of the different types of hazards (Berribilli et al., 2007) as presence of submerged rocks, channels, currents and the number of people on the beach (Short, 1999; Albuquerque et al., 2010). It can be higher or lower, depending on the degree of exposure of people to the events that may cause damage (Dal Cin and Simeoni, 1994; Dolan and Walker, 2004; Cervantes et al., 2015). The probability of accidents is related to: 1) a correlation between the level of knowledge of the beach users about the natural environment (sea) and the dangers present in the area and; 2) the occurrence of rip currents (Klein et al., 2003). These variables are poorly known at Recife urban beaches. Thus, this work aimed at evaluate the influence of the rip current warning signs on the use patterns of Pina and Boa Viagem beach and their possible outcomes.

2. Methods

2.1. Beach use

Recife urban beaches (8 km) are densely urbanized (Costa et al., 2008) and intensely used (Silva et al., 2008) both in density of people and time of the day-year (Silva et al., 2008). There are 11 lifeguard positions along these beaches. Some are fixed, equipped and permanently guarded; most are mobile and count on two crew (Fig. 1). Areas identified as of intense use (overcrowded) (Silva et al., 2006, 2008) (Fig. 2) were classified into four scenarios, according to presence or absence of rip currents (Maia et al., 2014) and red warning flags: (1) presence of rip current and absence of flag; (2) presence of rip current and flag in front of overcrowded area; (3) presence of rip current and flag nearby and (4) absence of both rip current and flag (Table 1). The number of beach users for these areas was determined in 2004 (before flags) and 2015 (after flags), under different management plans regarding this particular issue. Four transects (100 m wide and length of the whole sand area) were counted at 13:30 h (Silva et al., 2008), independent from tide, during seven consecutive days for beach users numbers (Table 2). The red warning flags within each transect were identified and georeferenced.

An ANOVA was made to determine the possible differences in numbers of beach users along the overcrowded beach areas (Ia, Ib, IIa, IIb, IIIa, IIIb, IVa and IVb) (Fig. 2) in 2004 and 2015. Where ANOVA showed a significant differences, an *a posteriori* Fisher LDS test was used to determine which overcrowded area presented significant differences ($p \leq 0.05$) (Fig. 2).

2.2. Drowning records

The databases of the Social Defense Secretary of Pernambuco (SDS) were consulted for drowning records from 1st January 2011 to 30th April 2016. Being responsible to conducting investigation in cases of violent deaths of any kind, the SDS follows an exhaustive protocol for data collection that includes detailed geographical and personal information in additional to documentation of the cause of death. The drowning records contain date, age, gender, beach location and drowning degree. The use of rip current signal was assessed using the software for Argus Image analyses.

The beach infrastructure to alert about dangers (ex. rip currents and shark attacks), number of lifeguards positions (fixed and mobile) available at the beach were identified, georeferenced and classified according to their operational conditions (Fig. 2).

A similarity matrix using the Bray-Curtis index was computed with drowning data using the software Past to assess the variability of this variable among beach areas. A cluster analysis was performed based on the similarity index, with distances calculated by frequencies of drowning for each overcrowded area (Ia, IIa, IIb, IIIb and IVa) in 2004 and 2015. The SIMPER analysis was used to define the percentage contribution of each item (#Flags, #Drownings, #Fatalities, Rip current) to the average dissimilarity between groups. Different groups identified were used *a posteriori* (cluster group as factor).

2.3. Images of beach user's behavior around signaled areas

Images from an Argus video system (Holman and Stanley, 2007; Holman et al., 2006), deployed on top of a building ~35 m high and ~25 m from the beach. At Boa Viagem, the system is composed of 5 cameras that cover 1.5 km in a 180° vision – images are both frontal and oblique. Images are captured and logged in situ every 30 min during daylight hours. Remote access to the images can be obtained by request. It was used to assess beach users (Balouin et al., 2014; Sadhu et al., 2016, 2017) and their behavior in relation to red warning flags for rip current. Images used were from Sunday to Saturday in order to observe the behavior and relative position of beach users to the rip current flag. The system is at the central area (IIb) (Fig. 1). Our study considered images from 19th (Sunday) to 25th (Saturday) October 2014, during austral summer, simultaneously to people counting. In this study, 179 oblique images were taken every 30 min from 5 a.m. to 6 p.m.

3. Results

3.1. Beach use patterns

The patterns of beach use were similar for 2004 and 2015, denoting overcrowding and surpassing of environmental and social carrying capacities in both occasions (Silva et al., 2008). However, in 2015 there was a wide variation in the number of beach users, mainly for area IIb. All beach parts had lost users in ten years (2004–2015). In the two sampling areas at the North of the beach, the average number of beach users in 100 m in 2004 was 1091 ± 552 SD and 307 ± 208 SD. By 2015, it was 440 ± 668 SD and 142 ± 226 SD. In the Central area, the average number of users dropped from 52 ± 80 SD and 106 1 ± 1367 SD in 2004 to 79 ± 38 SD and 448 ± 667 SD in 2015. The South part of the beach suffered smaller losses in the number of beach users (Fig. 3). The decrease in the use of beach represented about 40% in the North, and more than half in the Central and South areas.

3.2. Drowning events patterns

There were 403 drowning events registered between 2011 and 2016 (until July). The annual average was 67.17 ± 7.18 drownings $year^{-1}$, of which 5% resulted in deaths (Fig. 4). Yearly average number of deaths is 3 ± 3.63 fatal victims $year^{-1}$. The number of drowning events was higher before implementation of rip current signaling routine, dropping from 214 to 155 events per year (Fig. 5a). However, the number of drowning fatal victims increased at the central part (IIb and IIIb) of the beach (Fig. 5b).

Drowning at Recife urban beaches peak in March, January and