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Frequency Beach Profile Monitoring: Implications in Beach Safety at Cassino Beach, Southern Brazil

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ABSTRACT

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During the summer of 2002 and 2003, daily monitoring of beach profiles were conducted at Cassino Beach, a highly dissipative beach in southern Brazil in order to verify changes in the dynamic inner and outer bar systems which could provide additional information to beach safety programs. Distances and depths of the troughs from the water line oscillated between 55m and 0.89m respectively for the first trough, to 160m, and 1.78 m for the third trough. At low wave energy conditions, average migration rates of the first and second bar reached 4.8 m/day. The total number of accidents, in the summer 2002, were equally associated with both, dissipative and the intermediate morphodynamic states, however the accidents in the summer 2003 occurred only in the intermediate type. The presence of a deep trough imprint in the intermediate beach type, a higher hazardous morphology level. The 2003 campaign documented stable profiles, showing a low mobility and constant morphology with the same beach type, with a deep trough that reached the depth of 2.4m at a distance of 96m from the water line. It is believed that this low mobility was caused by the presence of mud bottoms at the nearshore zone.

ADDITIONAL INDEX WORDS: *Beach safety, bar migration, high frequency studies*.

INTRODUCTION

The scientific study of oceanic beaches addresses the increasing necessity of solving environmental problems related with the stability of the shoreline and maintenance of its aesthetic and environmental quality. These environmental problems are of natural and anthropogenic origins and have become progressively more significant in the socio-economic context of the coastal states in which they occur (SHEDDY *et al.*, 1993).

However, the crucial coastal management issue regarding the security of beach users has typically been considered to be of secondary importance. This matter directly impacts the welfare of the users of the beach environment and it demands from the managing states a considerable annual commitment. It requires financial mobilization in the form of lifesaving stations and patrolling campaigns, training of staff, and infrastructure generation (HOEFEL and KLEIN, 1998). Though this issue has been overlooked in the past, it currently deserves more scientific attention.

Beach hazards can be defined as the elements of the environment that expose beach users to harmful or life threatening dangers. Specific physical hazards include deep water, breaking waves, surf zone and beach topography variability, surf zone current variability (particularly rip currents, SHORT and HOGAN, 1993), as well as other localized hazards such as rocks, inlets and reefs. Based on these examples, a strict classification of permanent and non-permanent hazards can be made. In the scope of non-permanent hazards, bottom topography variations will be highlighted here, with special attention towards sandy beaches.

The present study analyze the variability of beach profiles, with focus on the inner and outer bar systems, with the objective of provide additional information about accident conditions, to beach safety programs being developed along the southern BraziLian coastline.

METHODS

Topographic surveys of high frequency (daily) had been carried out through the months of January, February and March, of the summer of 2002 and 2003, at Cassino beach (Rio Grande do Sul state, Brazil), situated three kilometers south of Patos Lagoon inlet (Figure 1) . In this place a concrete benchmark whose plain coordinates are X: 393666 and Y: 6440167 is located at the foredunes. The profiles were obtained with the use of a level and rod in accordance with the methodology described by the ISRP program (BIRKEMEIER, 1985). Significant wave height and period as well as number of bars were obtained by visual observations (MELLO, 1996).

RESULTS

During the three months of daily sampling, a total of 52 and 34 profiles were obtained in the summers of 2002 and 2003, respectively. Due to eventual adversities, such as strong fog, rain, winds and storm surges, the numbers of profiles obtained were not equivalent to the total number of sampling days (90).

The monitoring allowed to observe the sequential evolution of morphologic features such as berm, bars and troughs. The 2002 campaign documented a high diversity of morphologic situations ranging from a complete absence of inner bars up to three well developed bar systems along the sampled surf-zone. Figure 2 illustrates the shoreward migration development of a bar-trough system which moved 26.6 meters during a period of 5 days. This situation was also reproduced in two other occasions when the significant wave height and period coming from the Southeast and East quadrants were respectively lower than 0.75 meters and 10 seconds.

The 2003 field survey campaign documented stable profiles, showing low mobility and constant morphology keeping a deep trough of 2.4 m between the inner and outer bar at a distance of

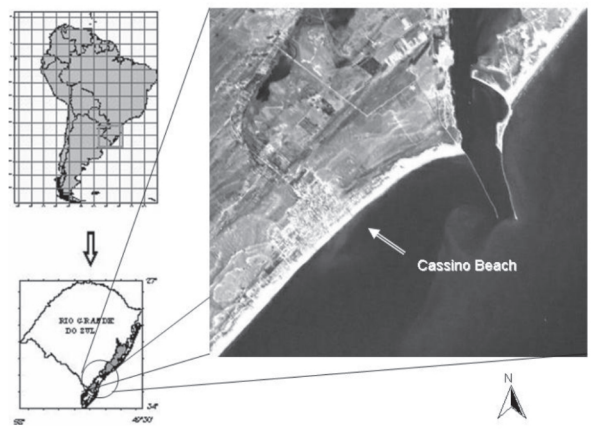

Figure 1. Location of the study area.

96 m from the water line. Such stability was probably related to the presence of muddy bottoms in the nearest surf zone which caused a remarkable damping of the wave energy observed during few storms, very similar to the process already described by CALLIARI *et al*. (2001) at the same beach. Figure 3 displays the profiles related to the bathing accidents.

Table 1 is based on the beach profiles envelope represented on Figure 4. It displays the number of occurrences of bar-trough systems and its mean, maximum and minimum distance from the shore as well as the corresponding depths related to the accidents occurred during the summer of 2002. Distance and depths are related to the maximum swash at the time of the surveyed profile. Bar crest distance and depth ranged from 49.7 m at 0.6 m up to 131 m at 1.3 m respectively. The distance and depth for the troughs ranged from 55 m to 160 m with the corresponding depths of 0.89 and 1.78 m. Data from other profiles indicate that depths at the deeper portion of the trough can be higher than 2.0 m exceeding by far the average height of the bathers. It should be noted that the number of bar-trough systems measured were limited by the applied methodology. TERRA (2003) using a sea sled at Cassino beach, identified four bar-trough systems across a 400 m beach profile.

The wave data analysis indicated a highly variable regime, alternating periods of high and low energy conditions. Most of the bathing accidents however, occurred during days of low wave energy (less than 0.75 m wave height) when incident wave energy was coming from the east and southeast quadrants. According to TOZZI and CALLIARI (2000), the South direction of incident waves is the one that presents greater wave energy, with the occurrence of moderate energy in Southeast conditions and relatively low energy in East condition. Similarly, the number of break lines ranged from six to one, with accidents mostly associated with two line of spilling breakers.

DISCUSSIONS

Average migration rates of the bar-trough system reached 4.8 m/day. However a close look at the Figure 2 shows that this rate can reach a maximum value of 5.3 m/ day during low wave energy conditions. GALLAGHER *et al*. (1998) studying bar migration next to Duck beach in North Carolina, Atlantic coast

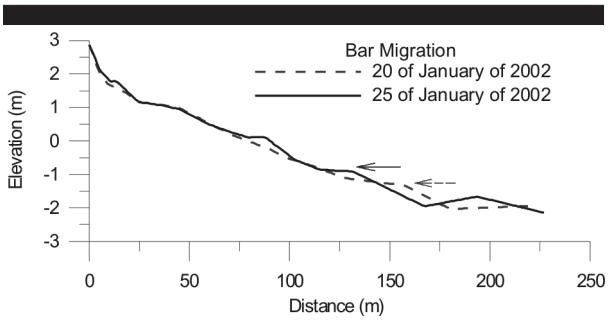

Figure 2. Wind data collected at Faro beach during July 2nd, 2003.

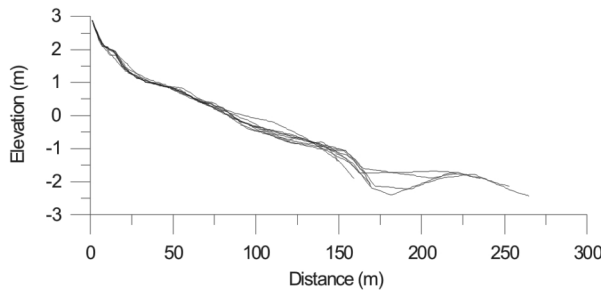

Figure 3. Profiles in days with bathing accidents. Summer 2003.

Of the United States, observed shoreward bar migration in situations of small waves, corroborating the results found in the present study. According to this author seaward migration occurs under conditions of high energy when the waves exceed 2 m and the bar migrate at a rate of 0.6 m/h.

Although a high diversity of beach profiles was register, there was no association of a higher number of accidents with a specific profile. They occurred at both, a plain profile with a gentle gradient and complete absence of bars to more steep profiles displaying up to three bars.

Accidents occurred in equal proportions for both dissipative and the long shore bar-trough intermediate beach stages (WRIGHT and SHORT 1984). According to SHORT and HOGAN (1993) the hazards related to dissipative beaches are associated to high waves and wide surf zones. In order to be safe, bathers should restrict themselves to the inner surf and the swash zone. For the bar-trough stage, the hazards are related to the presence of deep troughs, which are observed between the multiple bars, with depths greater than 2 m (Figure 5). This was the case for the present study since if we take into account the predominance of low energy regime during the study period, the bar-trough stage was the most dangerous. Additionally, suddenly increase of the sea-level due to barometric pressure changes has been registered in a stochastic way several times at this beach. Such still a poorly known phenomena that increases the potential hazard of this beach stage. During the summer of 2003 life guards stations closely spaced, registered at least 6 cases of rescue in a matter of 30 minutes. According to the life-guard commander, the accidents occurred to bathers who had crossed the deep trough but were actually in danger when they tried to return.

From Table 1 it is evident the high risk represented by the bar-

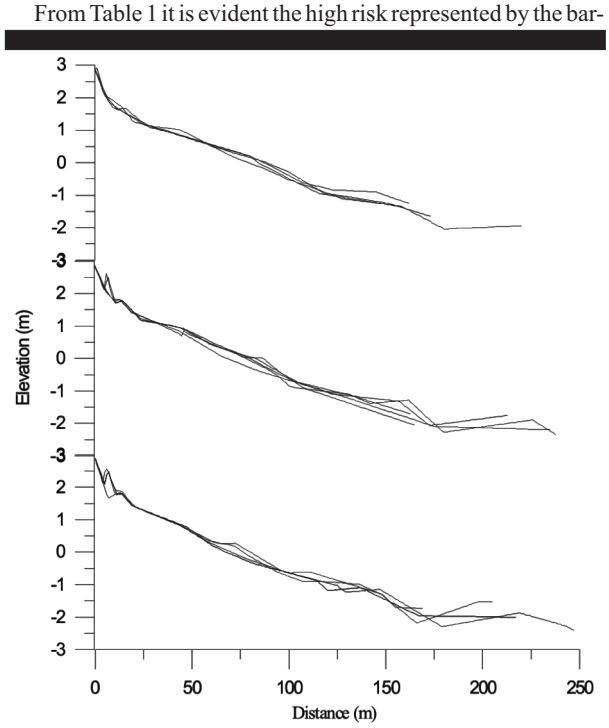

Figure 4. Profiles in days with bathing accidents. Summer 2002.

Figure 5. Digital aerial photograph of Cassino beach, showing a surf zone with multiples bars, taken by ADAR 1000 system (courtesy from Laboratório de Oceanografia Geológica).

Beach type	Wave Height (m)							
	<0.5	0.5	1.0	1.5	2.0	2.5	3.0	>3.0
Dissipative	4	5	6	7	8	9*	10*	10
Long Shore Bar Trough	4	5	6	7*	7*	8*	9	10
Rhythmic Bar Beach	4	5	6	6*	7*	8	9	10
Transverse Bar Rip	4	4	5*	6*	7	8	9	10
Low Tide Terrace	3	3*	4*	5	6	7	8	10
Reflective	2*	3*	4	5	6	7	8	10

Safety Rating

Safest: 1-3
Moderately safe 4-6
Low Safety 7-8
Least Safe 9-10

Key to Hazards

Water depth and/or weak current
Shore break
Rips and surf zone currents
Rips, currents and large breakers

Note: All safety level rating are based on a bather being in the surf zone and will increase with wave height or with the presence of features such as inlet, headland or reef induce rips and currents. Rip also become stronger with falling tide. * indicate safety level under modal wave conditions.

Figure 6. Beach hazard rating table presented by SHORT and HOGAN (1993).

trough systems. This is especially true for bathers with limited swimming capacity. Since the distance of the first trough is highly variable (4.5 m to 163 m) the safest zone for such users should be limited by the inner bar. According to the morphologic situations presented in Table 1 it appears that another dangerous situation is related to the presence of a second trough at a minimum distance of 47.5 m from the shore. It is also obvious from the table that the third trough is always hazardous. It also should be noted that all of these considerations are assumed to be at low energy conditions. During higher levels of wave energy the risk increases as already demonstrated by SHORT and HOGAN (1993). By using the data in the table presented before it's possible to adopt safety measures for delimitations of hazardous regions.

Most of the accidents (84 %) were related to the moderate safety rate according do the table proposed by SHORT and HOGAN (1993) Figure 6 (both dissipative and longshore bar-trough with waves lower than 1 m). Only 16% occurred under low safety rate (also dissipative and longshore bar-trough with waves higher than 1 m). HOEFEL and KLEIN (1998), studying the beaches of the central-northern coast Santa Catarina found similar results.

CONCLUSIONS

The daily profiles allowed to measure typical rates of bar-trough migration during the summer season for this particular beach. The average value of 4.8 m/ day indicates that even during low wave energy conditions the morphology changes quickly as faster as 19.2 m in 4 days. The presence of at least three bar-trough systems was identified. During 2003 only one bar-trough system was identified with the depth in the trough reaching 2.4 m. In this context the local authorities engaged on beach safety could use this data to improve safety measures both throughout education and even by practical measures of delimitating the distance and depth of the hazards represented by the troughs. Also, due to the fast beach profile survey bathers could be inform in almost real time of the topographic conditions. Such observation is only true for this beach since it is characterized by a low spatial change in beach morphology (TOZZI and CALLIARI, 2000).

It is clear that during the study period, the accidents were associated with low energy conditions, justly when the surf-zone becomes more attractive for most of the bathers. These conditions are characterized by waves with height less than 0.75 m coming from the East and Southeast quadrants and the presence of two break lines in the surf-zone. In most of the situations, there was complete absence of longshore currents. Accidents occurred in equal proportions for both dissipative and the long shore bar-trough intermediate beach stages (WRIGHT and SHORT 1984) demonstrating that there is no association between the number of accidents and a specific profile.

The fact the it is possible do "map" the distances of the bar-trough systems almost in real time, as well as, it daily migration rates raises the possibility of delimitate the most hazards areas using cables and floats adapted to the specific dynamic situations, specially during high beach usage, when the number of bathers is extremely high, a factor that increases considerably the risk (SHORT and HOGAN, 1993). The fact that sudden water level increase occurs at this beach should be considered at least under the focus of educational campaigns as well as technical aspects related to lifeguard training activities.

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Table 1. *Number of occurrences of bar-trough systems and its mean, maximum and minimum distance and depth linked to bathing accidents during the summer of 2002 at Cassino beach. The total number of profiles were 14.*

		Distance			Depth		
Features	**Occurrence**	**Mean (m)**	**Maximum (m)**	**Minimum (m)**	**Mean (m)**	**Maximum (m)**	**Minimum (m)**
First Bar	10	49,7	131,0	7,0	-0,60	-1,10	-0,05
First Trough	10	55,0	163,0	4,5	-0,89	-1,71	-0,25
Second Bar	8	94,3	135,0	56,5	-1,05	-1,65	-0,70
Second Trough	6	73,9	85,0	47,5	-1,51	-1,72	-1,07
Third Bar	1	131,0	131,0	131,0	-1,34	-1,34	-1,34
Third Trough	2	160,8	180,5	141,0	-1,78	-1,89	-1,67

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