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Sediment textural distribution on beach profiles in a rocky coast. (Estremadura – Portugal)

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ABSTRACT

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The Portuguese coast of Estremadura is a cliff dominant coast with small beach systems revealing a lack of sediments. The beach systems' behavior is almost unknown. In this coastal stretch, three beach systems were selected (S^{ta}. Rita, Azul and Foz do Lizandro) to understand sediment textural distribution over shore normal beach profiles. Collected data includes 143 superficial sand samples of the low tide terrace, base of the beach face, beach face and berm crest and 192 morphological beach profiles, between December 2005 and November 2006. The results show the importance of local sediment sources in beach textural distribution, namely cliff lithology and river discharge associated to a heavy rain event. This study reveals the absence of a longshore regional pattern. The textural distribution and maximum variability of the mean grain size along the intertidal morphologies was found to be well correlated between the selected systems. The base of the beach face recorded the greatest variation in sand mean size, contrasting with values observed in the beach face. The berm sediments prove to be considerable different from the grains of other morphologic elements and exhibit positive skewness linked to swash transport dominance over eolian deflation. Similar temporal trends of sediment textural distribution were found between the selected systems.

ADITIONAL INDEX WORDS: *beach sediments, cross-shore profiles, temporal analysis*

INTRODUCTION

Beach sediment textural distributions and waves control beach profile and shape and, ultimately, it's dynamic behavior. Slight local changes in grain size, shape or density can led to distinct morphological changes of the beach systems induced by the same energetic inputs. Sediment properties such as grain size, shape and specific fall velocity control the magnitude of sediment transport and the direction in which sediment travels, either in bedload or suspended transport by waves or currents.

In rocky coasts with small beach systems, local differences in sediment properties can be explained by environmental conditions such as episodic small river basins discharge, lithology of adjacent cliff systems or submerged geomorphological features of the inner continental shelf.

Field studies on textural distributions of beach sands are usually preformed along the beach profile (GUILLÉN and HOEKSTRA, 1996; MEDINA *et al*., 1994) and over several time scales from hours to years (MEDINA *et al*., 1994; STAUBLE and BASS, 1999).

The Portuguese Estremadura coast is a cliff dominant one with small beach systems' revealing a lack of sediments. The beach systems behavior is almost unknown. A monitoring program of beach systems morphodynamic is being performed since 2005, in order to supply this absence of information. Therefore, the main aim of this article is to evaluate beach sediment textural distributions over time and in different beach systems. However, local differences can be explained by environmental conditions such as different river discharge after rain events and lithology of adjacent cliff.

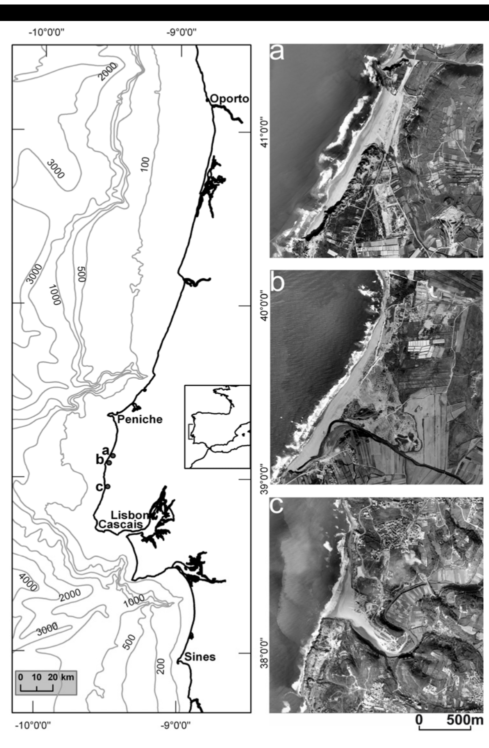

Figure 1. Study sites of Praia de S^{ta}. Rita (a), Praia Azul (b) and Praia da Foz do Lizandro (c).

Study sites

Portugal's West coast is a wave exposed coast with a highly energetic maritime winter. Atlantic atmospheric circulation explains wave climate regime in this area with NW predominant wave direction (265 days/year) and 2,5m mean winter offshore significant wave height (COSTA, 1994; OLIVEIRA PIRES, 1989). Extreme waves with a 5 year recurrence period can reach 9,2m of significant height (FERREIRA, 1993). Tidal wave propagates northwards along the coastline in a semidiurnal meso-tidal regime reaching the maximum amplitude at circa 4m. Coastal drift circulation is usually southward and has an estimated sediment transport ranging from 1,0x106m^3/y to 2,3x106m^3/y (OLIVEIRA *et al*., 1982; BETTENCOURT and ÂNGELO, 1992; TABORDA, 1993; VIDINHA *et al*., 1997; LARANGEIRO, 2002).

The coastline between Peniche and Cascais (Fig. 1), in the mid-West Portuguese coast, is a limestone cliff dominant one, lacking in sediment supply from longshore drift and local sources (ABECESSIS, 1987; PEREIRA, 1991). Longshore sediment transit towards the South is largely disturbed by the Nazaré canyon and the Peniche headland (VANNEY and MOUGENOT, 1981; VAN WEERING *et al*., 2002). The beach systems are narrow, embayed or associated to small river basin estuaries.

Information about beach sand properties in the Peniche – Cascais coastal sector is scarce. In different environments of source sediments and bedrock lithologies, previous studies show, in the northern sector of Portugal's West coast (South of Oporto, Fig. 1), that the mean beach sediment grain sizes can range from medium to coarse sands (0,48mm to 0,55mm) according to beach morphological components (FERREIRA, 1993; TEIXEIRA, 1994; TOMÁS, 1995; BOTO, 1997). Recent research in the southern coastal sector (North of Sines, Fig. 1) found the mean grain size as corresponding to coarse sands (GAMA, 2005; MIRANDA *et al*., 2008).

To understand short time changes and local differentiation of beach sediment textural parameters, three beach-dune systems are currently being monitored, namely S^{ta}. Rita beach, Azul beach and Foz do Lizandro beach (a, b and c, Fig. 1). The three beach systems are similarly exposed to wave climate, but distinct in size, shape and type. S^{ta}. Rita is a composite beach-dune / beach-cliff system. Beach-dune component occupies the North sector of the system and is 550m long and 150-200m wide. Azul beach is the second largest beach-dune system in the Peniche – Cascais coastal sector and is 1900m long and 975m wide. The southernmost and the smallest beach system included in this study is the beach-estuary system of the Foz do Lizandro. This system is 600m long and 200m wide.

METHODS

Superficial sediment samples were collected between December 2005 and November 2006 along a central profile in each beach system in order to evaluate grain size distribution and statistical parameters.

The sampling criterion was based on the presence of the most dynamic morphological elements of the beach profile including the low tide terrace (28 samples – maximum low tide point), the base of the beach face (40 samples – low tide terrace/beach face contact point), the beach face (40 samples – middle point) and the berm (35 samples – highest point).

Approximately 60g from each sample were washed and dry-sieved between -2,0ø and 4,5ø (0,5ø intervals) and weighed with a 0,01g accuracy. Statistics based on absolute frequencies of each fraction were obtained according to the logarithmic method of moments with the Gradistat spreadsheet (BOTT and PYE, 2001).

Systematic sediment sampling was followed by beach profiling monitoring campaigns. Total station and dGPS units were used to measure emerged beach morphometric changes resulting in 192 foreshore-backshore beach profiles. Results of the two survey techniques prove to be negligible in this dynamic context (TRINDADE *et al*., 2007).

Beach profile number and spacing aim to record data from the beach face and berm morphodynamics, resulting in 5 shore-normal profiles per campaign in S^{ta}. Rita beach, 6 in Azul beach and 5 in Foz do Lizandro beach. Beach profiles are anchored in fixed points away from the hydrodynamic area, ensuring overlapping between campaigns.

RESULTS

Beach systems textural distributions

Natural beach sediments can easily be characterized by using observed grain size statistical parameters either of the system or of several morphological elements of the beach. Often the most active elements of the intra-tidal zone are chosen to define the beach system sediments (DINGLER and REISS, 2002; SÉNÉCHAL *et al*., 2002; KULKARNI *et al*., 2004).

Intra-tidal beach sediments from S^{ta}. Rita, Azul and Foz do Lizandro are medium to coarse unimodal sands (WENTWORD, 1912).

Mean grain size at S^{ta}. Rita beach is 1,00ø (medium /coarse sands) and sands are well sorted (0,45ø). Mean diameters in this system range from 1,52ø to 0,37ø according to different morphological elements of the beach (Fig. 2) and over time. Maximum variability in mean grain size (Fig. 2) reaches the highest value at the base of the beach face (1,07ø) decreasing towards the beach face (0,64ø) and berm (0,59ø). Sorting measure values decrease from low tide terrace to the beach face, increasing in the berm (Table 1). Similar tendency is observed in the Azul and Foz do Lizandro beach systems.

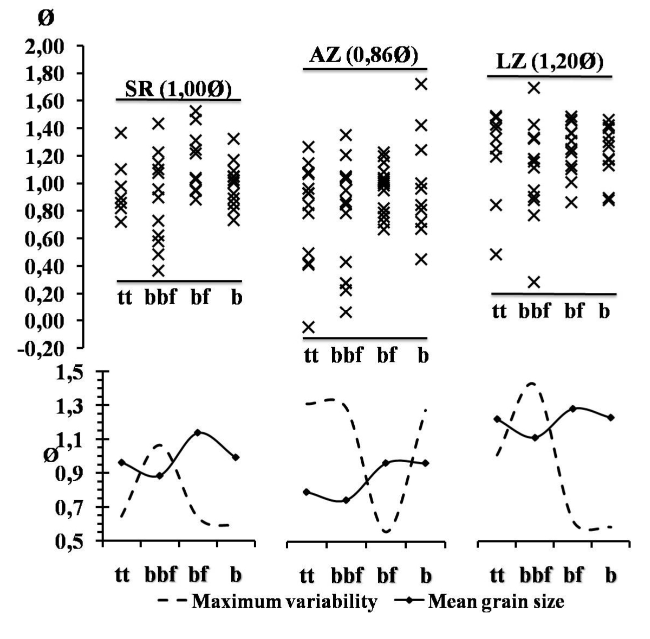

Figure 2. Mean grain size distributions and maximum variability in each system and according to observed morphologies. SR – Praia de S^{ta}. Rita; Az – Praia Azul; LZ – Praia da Foz do Lizandro; tt – low tide terrace, bbf – base of the beach face; bf – beach face; b - berm.

Table 1. Textural parameters according to beach system and beach morphology. $_{cs}$ – coarse sands; $_{ms}$ – medium sands; $_{ws}$ – well sorted; $_{mws}$ – moderately well sorted.

		tt	bbf	bf	b
SR	x (ø)	$0,96_{cs}$	$0,88_{cs}$	$1,14_{ms}$	$0,99_{cs}$
	σ (ø)	$0,54_{mws}$	$0,46_{ws}$	$0,41_{ws}$	$0,45_{ws}$
AZ	x (ø)	$0,82_{cs}$	$0,73_{cs}$	$0,96_{cs}$	$0,92_{cs}$
	σ (ø)	$0,53_{mws}$	$0,47_{ws}$	$0,36_{ws}$	$0,46_{ws}$
LZ	x (ø)	$1,21_{ms}$	$1,10_{ms}$	$1,27_{ms}$	$1,22_{ms}$
	σ (ø)	$0,51_{mws}$	$0,48_{ws}$	$0,42_{ws}$	$0,49_{ws}$

The Azul beach system has a mean sand diameter of 0,86ø (coarse sands - Fig. 2), ranging between 1,72ø and -0,05ø, and grains are moderately well sorted (0,52ø). This mean grain size range is the highest of the all systems and can be related to the size and type of the system. Like in the S^{ta}. Rita beach and also in the Foz do Lizandro beach, mean grain size within each system (Fig. 2 and Table 1) is coarser in the low tide terrace (0,96ø – SR; 0,79ø – AZ; 1,21ø – LZ) and in the base of the beach face (0,88ø – SR; 0,74ø – AZ; 1,10ø – LZ), contrasting with the beach face values (1,14ø – SR; 0,90ø – AZ; 1,27ø – LZ). The Azul beach maximum variability in mean sand size is higher at the base of the beach face (1,28ø) and clearly decreases in the beach face (0,56ø). This maximum variability behavior is similar in the three beach systems. Medium sands (mean grain size = 1,20ø) from Foz do Lizandro beach are well sorted (0,47ø) and mean diameters range from 1,69ø to 0,29ø.

Temporal analysis of the textural distributions

Beach face mean grain size values of each beach system in the period of analysis are expressed in Figure 3. An oscillation tendency over the time scale seems obvious and allows distinguish several periods with similar behaviors in the three beach systems. In the first month of sand size monitoring [Dec(1) and (2)], Azul beach and Foz do Lizandro beach sand size diameters have a coarsening tendency while S^{ta}. Rita beach experiences the opposite behavior (Fig. 3). Maximum differences in this period occur in the last two weeks of December (SR – 1,52ø; AZ – 0,79ø; LZ – 1,01ø). A clear relation between mean grain size and sorting is observed during this period, with a decrease tendency in sand diameter of S^{ta}. Rita beach associated to less sorted sands [Dec (2) – 0,48ø] and coarsening of the Azul beach and Foz do Lizandro beach sediments related to a better sorting [AZ Dec(2) – 0,35ø; LZ Dec(2) – 0,34ø].

Between Jan(2) and Feb(2), sands tend again to be coarser in the three beach systems (S^{ta}. Rita beach – 1,03ø ; Azul beach – 0,82ø; Foz do Lizandro beach – 1,10ø). Gradual coarsening of sands during this period is related to the occurrence of several storms (Fig. 3), registered in the wave buoys of Leixões, near Oporto, and Sines (Fig. 1). Sorting measure (Fig. 3) shows an evident relation between Hsmax peaks in January [Hsmax(Ls) Jan(1) – 5,99m; Hsmax(Ls) Jan(2) – 6,20m] and February [Hsmax(Sn) Feb(1) – 5,34m; Hsmax(Sn) Feb(2) – 6,28m] and a increase in standard deviation, meaning less sorted sands. The most positive values of skewness within this period indicate an over abundance of fines mixed with dominant coarser sediments in the beach face.

During March [Mar(1), (2) and Apr(1)], beach face sand diameters tend to be smaller [SR Apr(1) – 1,24ø; AZ Apr(1) – 1,01ø; LZ Apr(1) – 1,48ø] and better sorted than the previous period. This tendency follows a general decrease in Hsmax values (Fig. 3). The highest sorting value (most poorly sorted) and skewness values (fine over abundance) values observed at Azul beach in March [Mar(1)] are associated with a fluvial event and the terrestrial contributions from Sizandro river basin, after a heavy rainfall episode, registered in the nearby rain gauges (8,7mm/day in 17.03.2006; 26mm/day in 18.03.2006; 8,5mm/day in 19.03.2006, in Vimeiro rain gauge).

Azul beach is the only beach system with sediment data available for the entirely last period [May(2) to Jul(2)]. After an initial decrease in sand diameters grains tend to coarser fractions, reaching maximum coarsening in Jul(2) with 0,67ø. Skewness values clearly follow this coarsening tendency with a gradual decrease.

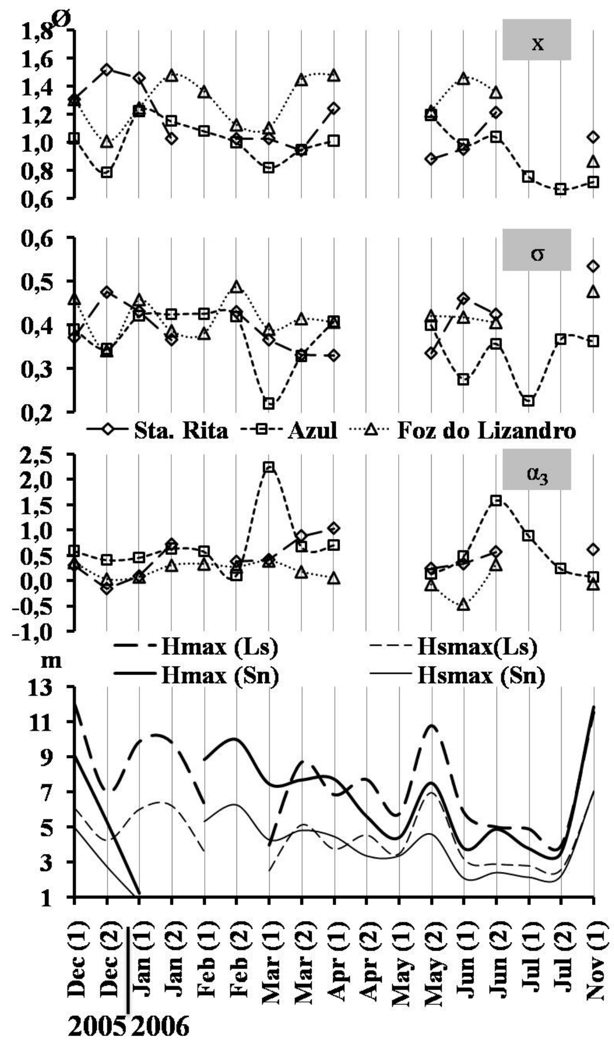

Figure 3. Beach face mean grain size (x), standard deviation (σ), skewness ($α_3$) in each system and Leixões (Ls) / Sines (Sn) offshore wave parameters (Hs – two week mean significant wave high; Hmax - two week maximum wave high; Hsmax – two week significant wave high peak); (1) – first two weeks; (2) – last two weeks.

DISCUSSION

The three beach systems reveal no clear regional trend in their mean grain diameter distributions. Differentiation in local sediment supply seems to have higher importance in defining the beach sands mean characteristic diameters. Although little is known about the inner continental shelf sediments close to the study areas, there are major differences between cliff rocks adjacent to the beach systems. Cliffs near Azul beach and S[ta]. Rita are cut in soft sandstones, conglomerates and clays while predominant bedrock materials cut in cliffs around Foz do Lizandro beach are limestones and clays (NEVES, 2006).

Despite differences in mean and sorting of sands in the three beach systems, the analysis of the mean grain diameter distributions and maximum variability in grain size in the intra-tidal zone of the beach reveals a similar behavior between systems. The observed coarse and poorly sorted sands in the low tide terrace and in the base of beach face is a common feature in the three beach systems and may be due to successive bore collapse and high tide plunge point position over the base of the beach face in the inner surf zone. The reformation of incident waves after the first breaking point over the bars cause a second break point at the base of the beach face and a coarsening in beach sediments in this sector of the beach profile (GUILLÉN and HOEKSTRA, 1996, 1997; KOMAR, 1998).

The beach face experiences a considerable decrease in the grain size diameters when compared to the base of the beach face. Maximum variability in mean grain sizes is also more expressive between these two morphological elements proving a major general shift in the energy of the depositional agent. In this sector of the beach profile swash hydrodynamics tend to a decrease in flux velocities and, therefore, lead to a decrease in the magnitude of the sediment transport up the beach face (MASSELINK and HUGHES, 1998).

Relationships between the mean grain size and the slope of the beach are expressed in Figure 4. These two parameters do not seem to be linked, as there is no clear trend, exception made do Lizandro beach. In this system, the polynomial trend shows finer sands in increasing slopes. This behavior was not expected as the higher slope values are usually related to reflective tendency (SHORT, 1999), i. e., lower wave energy that can only mobilize the fine sand, leaving the coarse one behind.

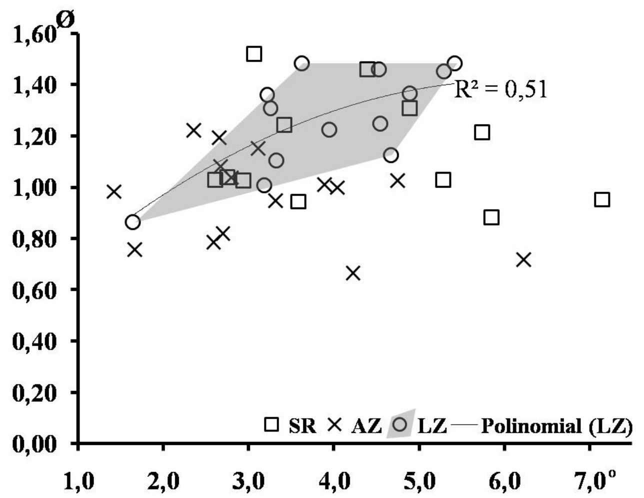

Figure 4. Relationship between mean grain size and beach face slope in all studied systems.

Finally, a slight coarsening is observed between the beach face sediments and the berm. According to Bascom (1951), the berm sands coarsening can be explained through the eventual berm crest overtop by wave uprush and constant eolian deflation over fine grained fractions. Therefore, it would be expected that coarsening of the berm sands would result in more coarse skewed grains. This was not observed in the sediment texture parameters from the three beach systems (Fig. 5). The relationship between mean sand diameters and skewness illustrates that berm sands have a distinct sediment distribution with an over abundance of fines mixed with dominant coarser sediments. This over abundance increases as grains get coarser (Fig. 5) showing that the swash selective transport is dominant over aeolian modes of sediment transport.

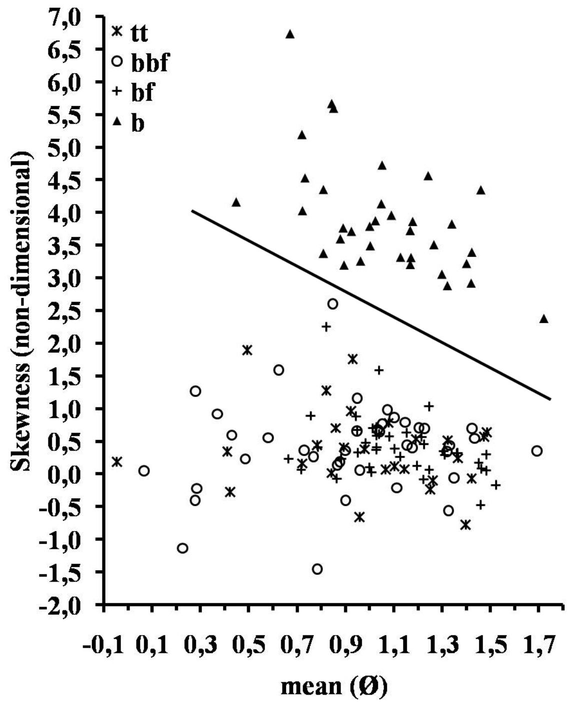

Figure 5. Relationship between mean grain size and skewness in all beach systems in the different morphological elements of the beach.

CONCLUSION

The study of beach systems' textural distributions and morphodynamics carried out in Estremadura reveals some important conclusions.

The studied systems are representative of a coastal cell, according to KOMAR (1998), as the sediments in transit by the longshore drift are captive by the Nazaré canyon and the local contribution of sediments is the main source even if scarce, considering the small river basin and the predominant limestone cliffs.

The local small differences in cliff lithology seem to be responsible for coarser sands and the absence of a longshore regional pattern. However, textural distribution and maximum variability of the grain mean size along the intertidal morphologies are consistent between the studied beach systems. The main differences in the grain properties are observed between the base of the beach face and the beach face. The base of the beach face is the morphodynamic element with greater variation in mean size sand, in all the three studied systems, as a result of a second break of the wave.

Temporal distribution of sand parameters usually follows the same trend in the different systems. However a distinctive behavior was registered that probably is connected to differences in nearshore wave refraction field.

The correlation between mean sand diameters and skewness allowed to distinguish the berm sediments and to establish the swash transport as dominant over eolian deflation in this morphodynamic element.

Skewness distributions over time made possible identify a specific terrestrial contribution associated with a heavy rain event.

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The body of a paper should generally include, in order, 1) an introduction, 2) methods, 3) results, 4) analysis, 5) discussion, 6) conclusion, 7) acknoledgement. **Do not use numbering systems**

The body of paper should be in times new roman 9 font normal.

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The S.I. system (le System International d' Unites) of reporting measurements, as established by the International Organization for Standardization in 1960, is required insofar as practical. Other units may be reported in parentheses or as the primary units when it would be impossible or inconvenient to convert to S.I. Equivalent units may be given in parentheses when tables, figures, and maps retain units of the English system (Customary units).

Table 1: Structure of standart script of interviews with public users of patrolled beaches (HOEFEL and KLEIN, 1998).

Social data	Knowledge of the beach
Sex	Familiarity
Origin	Frequency of use
Family Income	Depth of sea bathing
Level of Education	Potencial signs of danger to sea bathing
Age Group	Precautions taking when getting into water
Swimming ability	Degree of danger of the sea
Involvement in bathing accidents	Precaution taken in relation to children

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$$\frac{R_x}{R_0} = C_1 + C_2\left(\frac{\beta}{\theta}\right) + C_3\left(\frac{\beta}{\theta}\right)^2 3 \qquad (1)$$

TABLES

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LITERATURE CITED

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GIAMMONA, C.P, 1988. Sea surveys. In: Finkl, C.W, Jnr. (ed.), The Encyclopedia of Field and General Geology. New York: Van Nostrand Reinhold, pp. 747-764.

MCCAVE, I.N., 1987. Fine sediment sources and sinks around the East Anglian coast (UK). *Journal Geological Society London*, 144, 149-152.

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KUNDU, PK, 1990. *Fluid Dynamics*. New York: Academic, 638p.

MEHTA, AJ. and MONTAGUE, C.L., 1991. A Brief Review of Flow Circulation in the Vicinity of Natural and Jettied Inlets: Tentative Observations on Implications for Larval Transport at Oregon Inlet, North Carolina. Gainesville, Florida: Oceanographic Engineering Department, University of Florida, Report UFLICOELIMP91 / 03, 74p.

Check the accuracy of your references scrupulously. Many papers arrive at a reviewer's desk with incorrect dates, titles, and author names in reference lists; or one year of publication or spelling of the author's name in the reference list and another in the text citation. Responsibility for accuracy rests solely with the author. Examples of variations on the basic citation formula follow.

Examples of Reference Formats for the ICS2009

(check the CERF WWW site http://cerf-jcr.org/author_instruction-1.htm for additional details)

Single-Author Paper in a Journal

Dickinson, W.R., 2000. Hydro-isostatic and tectonic influences on emergent Holocene paleoshorelines in the Mariana Islands, western Pacific Ocean. *Journal of Coastal Research*, 16(3), 735-746

Two-Authored Paper in a Journal

LIDZ, B.H. and HALLOCK, P., 2000. Sedimentary petrology of a declining reef ecosystem, Florida Reef Tract (U.S.A.). *Journal of Coastal Research*, 16(3), 675-697

Multi-Authored Paper in a Journal

MARTINEZ, J.O.; GONZALEZ, J.L.; PILKEY, O.H., and NEAL, W.J., 2000. Barrier island evolution on the subsiding central Pacific Coast, Colombia, S.A. *Journal of Coastal Research*, 16(3),

Figure 2. An example of a figure considered to two columns

Table 1: Structure of questionnaire for reporting the conditions of bathing accidents, used by lifeguards to register accidents (HOEFEL and KLEIN, 1998).

Header	Part A:	Part B:	Part C:
	Nature of victim	Rescue date	Beach characteristcs
Town	Sex	Type of rescue	Type of morphology

663-674.

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BUTENKO, J and BARBOT, J.P., 1980. Geological hazards related to offshore drilling and construction in the Oronoco River Delta of Venezuela. *Offshore Technology Conference* (Houston, Texas), Paper 3395, pp. 323-329.

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WORTHY, M.C., 1980. Littoral Zone Processes at Old Woman Creek Estuary of Lake Erie. Columbus, Ohio: Ohio State University, Master's thesis, 198p.

ARENS, S.M., 1996. Aeolian Procrresses in the Dutch Foredunes. Amsterdam, The Netherlands: University of Amsterdam, Ph.D. thesis, 150p.

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Maps or Charts

BELTRÁN, C., 1993. *Mapa neotectónico de Venezuela*. Caracas, Venezuela: FUNVISIS Departmento de Ciencias de la Tierra, scale 1:2,000,000, 1 sheet.

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New affiliations, contribution numbers from institutions, and financial support from research contracts and grants may be added here.