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Nearshore currents and safety to swimmers in Xai-Xai Beach

Correntes costeiras e segurança de banhistas na Praia de Xai-Xai

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ABSTRACT: Xai-Xai Beach is a shallow semi-enclosed lagoon, about 2,000m long, 200m wide and 3m average depth, protected from ocean swell by a reef about 0.75m above the Mean Sea Level, with small gaps along its extension. Despite being protected from ocean waves, the lagoon, which is popular with tourists, is a dangerous place to swim, with an average of 8-9 drownings each year. The present paper examines the longshore and rip currents in the lagoon as the potential cause for these fatalities. Drifters were deployed for measuring the magnitude and direction of the nearshore currents. Unidirectional, northwards, longshore currents, with velocity up to 1.4ms^{-1} and strong rip currents, with velocity up to 3.4ms^{-1}, 5-10m width and duration of less than 5 minutes, were observed. The observed rip currents pose a real danger even to experienced swimmers, hence it is concluded that they are the major cause of the deaths. The areas of major incidence of rip currents were identified. The result allows us to recommend a zoning of the beach into three areas as follows. The southern part, with weak currents, is classified as a "safe area", flagged green, and is recommended for swimming. The northern part, with strong rip currents, is classified as a "hazardous area", flagged red, and prohibited for swimming. In the intermediate zone, classified as a "moderate area" and flagged yellow, swimmers should proceed with caution. Regular patrols by lifeguards and beach assistants are highly recommended during the summer, the peak tourism season.

Keywords: longshore currents, channel rip current, swimming, drowning, beach zoning, beach safety

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RESUMO: A Praia de Xai-Xai é uma lagoa semifechada pouco profunda, com cerca de 2.000m de comprimento, 200 m de largura e 3 m de profundidade média, protegida por um grés de cerca de 0,75m de altura acima do Nível Médio do Mar, e com aberturas e fissuras ao longo da sua extensão. Apesar de estar protegida das ondas do oceano tem havido relatos de mortes, em média 8 a 9 casos por ano, devido a afogamentos. Neste trabalho investigam-se as correntes de deriva litorânea e de retorno como as potenciais causadoras dos afogamentos observados. Boías de deriva foram lançadas na praia para medir a magnitude e direção das correntes costeiras. Observou-se uma corrente unidirecional para o norte com intensidade média de 1,4ms^{-1} e correntes forte de retorno com intensidade média de 3,4ms^{-1}, e com 5-10m de largura e um período de cerca de 5 minutos. As correntes de retorno observadas constituem perigo mesmo para nadadores experientes, daí que são consideradas as principais causadoras dos afogamentos observados na Praia de Xai-Xai. Os locais de incidências destas correntes foram identificados. Os resultados permitiram o zoneamento da praia em: parte sul, com correntes fracas, classificada como "área segura" e sinalizada com bandeirolas de cor verde, recomendada para natação; parte norte, com fortes correntes de retorno, classificadas como "área de risco" e sinalizada com bandeirolas de cor vermelha, onde a natação deve ser proibida; e a zona intermediária, classificada como "área moderada" e sinalizada com bandeirolas de cor amarela, onde a natação deve ser realizada com cautela. Recomenda-se a patrulha periódica por autoridades do corpo de salvação pública e monitoria permanente por unidades de salva-vidas durante o verão, o período do pico de turismo.

Palavras-chave: deriva litorâneos, corrente de retorno fixa, nado, afogamento, zoneamento da praia, segurança na praia.

1. INTRODUCTION

Nearshore current systems can be divided into three types, namely: the shoreward mass transport of water; longshore currents; and seaward-moving rip currents (Tang *et al.*, 2012). The currents are mainly driven by surface wave activity in the surf zone, enhanced by the topography. Waves approaching the shoreline obliquely break in different places at different times, resulting in a differential wave set-up, a process described by the theory of radiation stress (Longuet-Higgins, 1970). This is the main process for generating longshore currents that flow parallel the beach. Rip currents result as a response to an excess of water built up on shore produced by the combined effect of the breaking waves and convergence of longshore currents. The rip currents are strong, concentrated, episodic bursts of water flowing seaward. They are short lived, unpredictable in space and time, and extend from close to the shoreline through the surf zone to varying distances beyond (Brander, 2018). The rip flow is concentrated through the breaks or depressions in the sand bars (Leatherman, 2012).

Rip currents are said to be the major cause of danger to recreational beach users, claiming hundreds of lives by drowning and causing thousands of rescues worldwide every year (Brander, 2018; Arun Kumar & Prasad, 2014; Meadows *et al.*, 2011; Lushine, 1991; Short & Hogan, 1994; Bowen, 1969). Rip currents are reported to be responsible for more than 100 drowningss and for 80% of surf rescues each year in the U.S. alone (Meadows *et al.*, 2011; Lushine, 1991; Lascody, 1998). Houser *et al.* (2011) stated that many drownings and near drownings at Pensacola Beach, Florida are attributed to rip currents. The fact that they are unpredictable makes them even more dangerous. Linares *et al.* (2019) reported seven deaths due to unexpected rip currents, created within minutes by a storm from initially calm conditions, on a beach in Lake Michigan on July the 4th 2003.

According to the Mozambique Maritime Administration Authorities, 42 casualties by drowning were observed in Xai-Xai Beach during the period 2011 to 2014, as follows: 14, 12, 9 and 7 in 2011, 2012, 2013 and 2014, respectively, averaging 10 occurrences per year. According to Christensen *et al.* (2013) the numbers of casualties from drowning on Xai-Xai Beach were on average 8-9 per year during the period 2010-2014. The cause of the casualties on Xai-Xai Beach are not well known; however, based on the reports from other locations, it seems possible, even probable, that nearshore currents are the main cause of the drowning at Xai-Xai. The aim of this study is to test the hypothesis that the longshore and rip currents are potential causes of drowning on Xai-Xai Beach. Based on the result of the study, beach zoning can be introduced, indicating areas which are safe and which are dangerous for swimming. Patrol services by lifeguard and beach assistants are also recommended.

According to Castelle *et al.* (2016) there has been a growing interest in nearshore currents, particularly rip currents, in recent decades, by both the scientific community and society in general. The increasing interest is a result of the dangers they pose to swimmers and as well as their importance to the transport and cross-shore mixing of heat, pollutants, nutrients and biological species. Sabet & Barani (2011) investigated rip currents along the southern coast of the Caspian

Sea, using GPS drifters, similar to the one used in the present study, and moored current meters. Scott *et al.* (2018) also used drifters to measure nearshore currents in Bight of Benin coast, in Gulf of Guinea, West Africa. MacMahan *et al.* (2005) measured rip current kinematics and beach morphodynamics at Sand City, Monterey Bay. The fact that strong nearshore currents occur in the breaker and shallower zones with harsh wave conditions makes it difficult to moor equipment for observations (Shafiei Sabet & Barani (2011a)). Instead, there has been an increase in the use of Lagrangian methods, using floats and drogues, to observe and measure rip currents (Castelle *et al.*, 2016). In addition, numerical models are increasingly used to predict nearshore currents. Wind & Vreugdenhil (1986) analysed field data and modelled wave-driven current systems in a closed basin. Barreiro & Bühler (2008) presented a numerical investigation of longshore currents driven by breaking waves on barred beaches.

There are a few existing studies of the nearshore currents on the Mozambican coast. An earlier study of Xai-Xai Beach investigated the waves and currents and found that the beach is characterised by a strong unidirectional northwards longshore current, thought to be due to the effect of the barrier reef, where the ocean swell breaks and spills water over into the beach lagoon (Christensen *et al.*, 2013; Silva, 2012). Taskjelle *et al.* (2014) modelled the tides and longshore currents in Xai-xai Beach lagoon, forced by tides and ocean waves modified by the reef. The model results are in agreement with observations. Christensen *et al.* (2013) found that strong rip currents were associated with the gaps in the reef and proposed the hypothesis that these currents were generated near the beach and fed by the strong longshore currents. Similar observations were made by Nharreluga (2014) when studying the factors influencing the longshore currents in Xai-Xai Beach. It was concluded that the determining factors were the tides, ocean wave height and the height of the reef above Mean Sea Level. This concords with the Handbook of Beach and Shoreface Morphodynamics (Short, 1999).

2. DESCRIPTION OF THE AREA

Xai-Xai Beach is located at Latitude 25º 07'S and Longitude 33º 44'E (Figure 1). It is a sandy beach lagoon, fringed by a reef. The inner lagoon is about 2 km long, 200 m wide and 3 m average depth (Figure 1). The reef is about 20m wide and elevated 0.70m above Mean Sea Level, with gaps along its extension. The tidal amplitudes vary from 0.5m to 1.5m between neap and spring tide (Taskjelle *et al.*, 2014, Sete *et al.*, 2002). The significant wave height of the ocean waves is between 0.75m and 1.5m, depending on wind conditions; waves in the lagoon have an average height of 0.4m and a period of about 12-16 seconds (Christensen *et al.*, 2013). Waves hit and break on the reef and spill water over the beach lagoon setting up a strong longitudinal pressure gradient force causing strong longshore currents towards the north (Christensen *et al.*, 2013). Most of the wave energy, about 97%, is dissipated on the reef (Silva, 2012).

Xai-Xai Beach receives on average 22,000 tourists per year, about 50% of which are foreigners. The peak season is during the southern summer, about December/January. During the period 2003-2008 the tourism industry in Xai-Xai contributed to the government taxes on average USD50,000 per annum, and provided about 100 direct and 500 indirect jobs (Anon, 2009). Despite the fact that the beach is protected from ocean waves there are reports of casualties by drowning (Christensen *et al.*, 2013). There are no permanent lifeguard services in Xai-Xai Beach nor is there a flagging or sign system.

3. DATA

For the present study, data on current speed and direction obtained by means of a specially constructed Lagrangian drifter buoy were used. The buoy is similar to that built and described by Shafiei Sabet & Barani (2011a), designed specifically to track coastal currents. The buoy consisted of a spherical float of 0.30m diameter, stabilized by a heavy weight located at the bottom, on an axis of about 0.50m height across its poles, all weighing 5.5kg. When in the water, about 70% of the sphere was submerged. Apart from stabilizing the buoy, the heavy weight dampens the drifter's vertical response to rapid changes in water level, allowing broken and near-breaking waves to pass over without rapidly pushing the drifter ashore. A GPS receiver Garmin Astro 440 was attached to the buoy and sent data, via radio waves through a DC 40 transmitter, to a hand-held data logger at sampling rate of 0.2Hz (Figure 2). The drifter is small, simple and low-cost, and appropriate for measuring surface currents in shallow-coastal environments. In addition, the drifter is deployed and recovered by hand and can easily be used for repeated runs over a short period of time. Their ease of deployment makes them effective for measuring rapidly developing transient features, as noted by Shafiei Sabet & Barani (2011a).

The field methodology for tracking the coastal currents applied in the present study is similar to that described and discussed by Schmidt *et al.* (2003) and further applied by Shafiei Sabet & Barani (2011b) for tracking the rip currents along the southern coast of the Caspian Sea. In the present study, however, a single drifter buoy was used repeatedly.

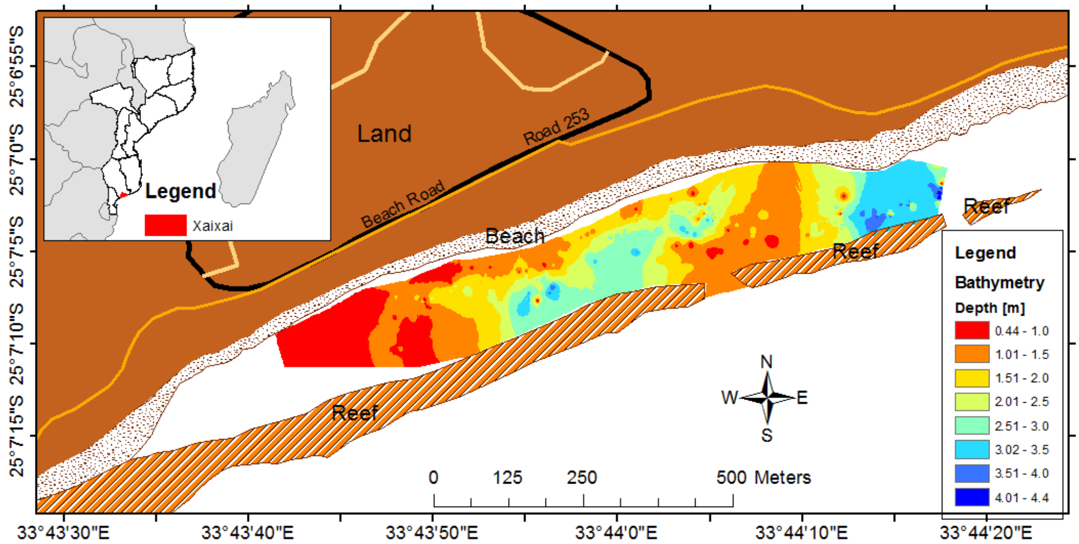

Figure 1. Location map of the study area. Bathymetry is given in meters.

Figura 1. Localização da área de estudo. Batimetria é dada em metros.

Mapping the rip current risk by determining the spatial occurrence of rip currents based on the observations, morphology of the reef, e.g. the presence of gaps along the reef and by considering the velocity and direction of the rip currents, enabled a zoning plan for the beach according to the methodology applied by Lee *et al.* (2016).

The observations were made during the period 8 to 18 March 2011, covering Neap and Spring tides. During that period 12 tracks of along shore and 5 tracks of rip currents were followed.

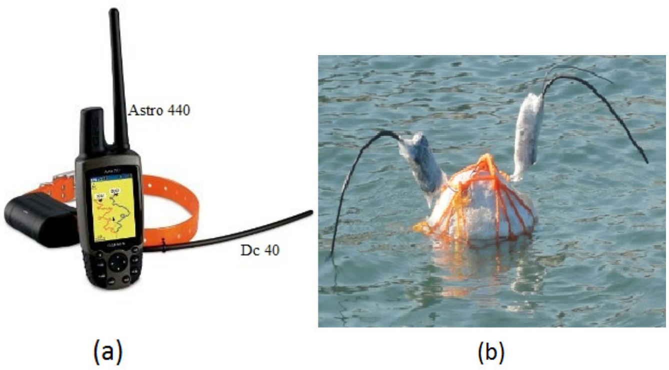

Figure 2. GPS receiver Garmin Astro 440 and a transmitter DC 40 (a) and a drifter buoy in water (b).

Figura 2. Receptor GPS Garmin Astro 440 e o transmissor DC 40 (a) e a boia de deriva na água (b).

4. RESULTS AND DISCUSSION

4.1 Longshore currents

Figure 3 presents the drifters' tracks for longshore currents. It can be seen that the currents are directed towards the north and to the coast. The longshore current speeds are presented as time series plots in Figure 4, and Table 1 summarises the velocity measurements. During the flooding spring tide (Track 1 and Track 4), the average velocity was about 0.08ms^{-1} and 0.15 ms^{-1} for Track 1 and Track 4, respectively. In Track 1 the velocity varied between 0.03 and 0.56 ms^{-1} and remained most of the time at about 0.1-0.2 ms^{-1}. In Track 4 it varied between 0.05 and 0.5 ms^{-1}, and remained at about 0.1 and 0.4 ms^{-1} most of the time. Two levels of velocity can be observed. During the ebbing spring tide (Tracks 5, 8 and 9) the velocities varied from 0.5 to 0.8 ms^{-1}. In Track 5 the average velocity was 0.31ms^{-1}; the excursion was 148 m in 577 s (9 min and 37 s); in Track 8, the total excursion was 293.1 m in 1132 seconds (18 min and 52 s), which led to an average velocity of 0.26 ms^{-1}. In Track 9 the excursion was 345 m in 13 min, leading to an average velocity of about 0.78 ms^{-1}. Clearly, the longshore ebb velocities were notably higher than the flood velocities. Furthermore, the longshore velocities at the northern part of the beach were high compared with the velocities in the southern beach.

During the flooding neap tide (Track 10) the longshore velocities ranged from 0.03 to about 0.56 ms^{-1}, with an average speed of 0.19 ms^{-1}. The excursion was 269 m in 143s (23 min and 52 s). During the ebbing neap tide

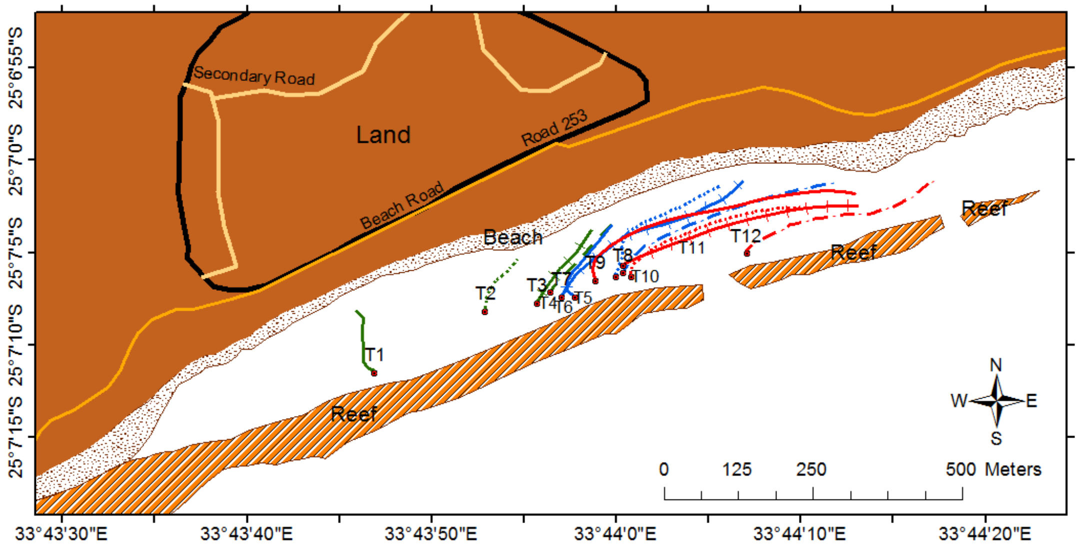

Figure 3. Longshore current drifter tracks. The deployment points are indicated by the dots. Xai-Xai Beach, 8-18 March 2011.

Figura 3. Trajetórias de correntes de deriva litorânea. Os pontos de lançamento são indicados pelos pontos. Praia de Xai-xai, 8-18 de Março de 2011.

(Track 12), the velocity varied from 0.05 to 0.8 ms^{-1}, toward the north. The total excursion was 322 m in 915 seconds (15 min and 15 s), which led to an average velocity of 0.24 ms^{-1}. Once again, the ebb velocities are higher than the flood velocities and increased with distance towards the north.

Table 1 presents the summary of all deployments for longshore currents. The recorded magnitude of the average longshore velocity was in the range 0.08-0.31 ms^{-1}, except in track 9 which was 0.78 ms^{-1}. These values fall within the range obtained in other places. Sabet & Barani (2011) investigating rip currents along the southern coast of the Caspian Sea, using GPS drifters, similar to the one used in the present study, and moored current meters, recorded longshore currents within the range 0.10-0.35 ms^{-1}. Siswanto (2015) recorded longshore currents of magnitude 0.87-0.92 ms^{-1} in Madura Strait. Linares *et al.* (2019) observed longshore velocity up to 0.6 ms^{-1}, in association with the occurrence of meteotsunami on southeastern beaches of Lake Michigan. Barreiro & Bühler (2008) using numerical models simulated longshore velocities as low as 0.05 ms^{-1} to as high as 1.5 ms^{-1} on a barred beach, with similar morphology to the reef in the present study. Wood & Meadows (1975) on investigating unsteadiness in longshore currents recorded an instantaneous velocity of 0.3-2.0 ms^{-1}. Scott *et al.* (2018), using drifters, found longshore current velocities in the range 0.2-0.8 ms^{-1} in Bight of Benin coast, in Gulf of Guinea, West Africa.

Combining Table 1 and Figure 3, it can be seen that the currents are unidirectional, towards the north, regardless of the tides. This behaviour is thought to result from a pressure gradient set up by the waves breaking and spilling water over the reef into the southern part of the beach lagoon. Water then flows from the south to the north where it escapes through gaps in the reef, as explained by Christensen *et al.* (2013) and Taskjelle *et al.*(2014).

From Table 1 it can be seen that the ebbing velocities were higher than the flood velocities and from the tracks (Figure 3) it can be seen that the direction of the currents is northwards, regardless of the tide. This is a result of flow induced by the waves breaking on the reef flat as explained by Christensen *et al.* (2013) and Taskjelle *et al.*(2014), also observed by several authors (Kraines *et al.* 1998; Symonds *et al.* 1995; Hearn & Parker 1988; Nadaoka *et al.* 2001). Further, it is evident that the longshore currents in the southern beach (Tracks 1-8) are weaker compared to the mid and northern part of the beach (Tracks 9-12), suggesting low-energy environments in the southern beach, and hence, a safer place for swimming.

4.2 Rip currents

Given the fact that rip currents are sudden, narrow and short lived, they were seen in few deployments during the duration of the observations. Figure 5 presents the drifters' tracks for rip currents. In addition, through visual observation (Figure 6) it was possible to see the rip currents and understand that they are quasi geostationary in the vicinity of reef gaps. Figure 7 presents the time

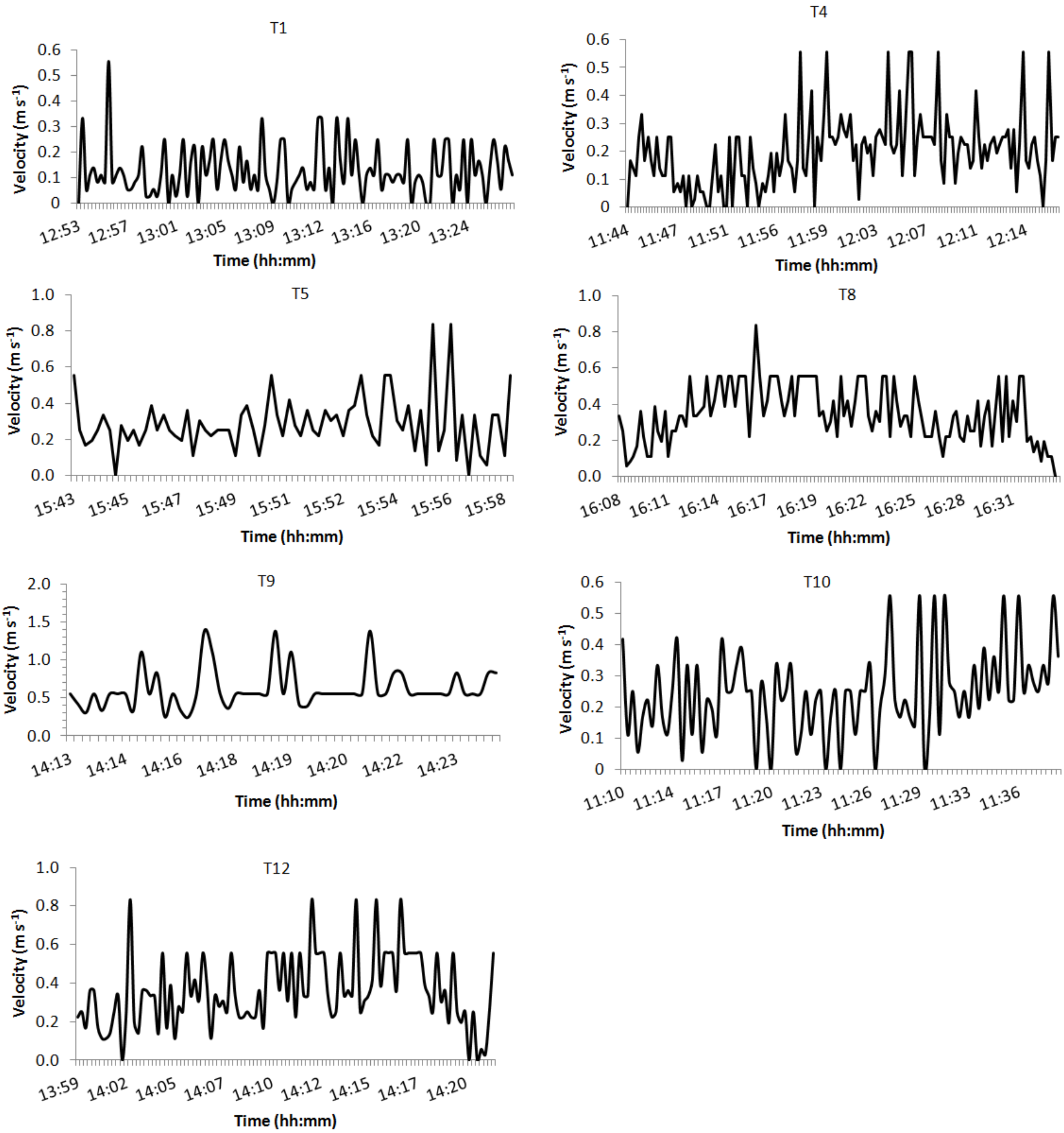

Figure 4. Time series of the longshore current velocity. Xai-xai Beach, 8-18 March 2011.

Figura 4. Série temporal da velocidade de correntes de deriva litorânea. Praia de Xai-xai, 8 a 18 de Março 2011.

Table 1. Summary of the deployments for longshore currents. Xai-xai Beach, 8-18 March 2011.

Tabela 1. Sumário das observações de correntes de deriva litorânea. Praia de Xai-xai, 8 a 18 de Março 2011.

Track	Tide regime	Distance (m)	Period (s)	Average velocity (m s^{-1})
T1	Flooding Spring	120.7	1740	0.078
T2	Flooding Spring	96.6	1732	0.078
T3	Ebbing Spring	155.2	1260	0.123
T4	Flooding Spring	172.4	1677	0.153
T5	Ebbing Spring	148.3	577	0.314
T6	Flooding Spring	213.8	1409	0.152
T7	Ebbing Spring	460.3	1155	0.080
T8	Ebbing Spring	293.1	1132	0.259
T9	Ebbing Spring	344.8	758	0.781
T10	Flooding Neap	224.1	1740	0.216
T11	Flooding Neap	269.0	1431	0.188
T12	Ebbing Neap	321.7	915	0.241

series plots of the observed rip currents. During the flooding neap tide the peak velocity reached 0.33 ms^{-1} and 0.25 ms^{-1} in Track 1 and Track 3, respectively. During the ebbing neap tide (Track 2) the peak velocity reached up to 1.4 ms^{-1}. Track 4 portrays a rip current crossing through the gap to the open ocean, with peak velocities up to 3 ms^{-1}. Track 5 depicts a combination of longshore and rip current with peak velocities up to 1.4ms^{-1}. Both Track 4 and Track 5 occurred during the ebbing spring tide. Once again the ebbing velocities were higher than the flooding velocities, and on average, low velocities were recorded in the southern beach (Track 1-3) and highest velocities were recorded on the northern beach (Track 4 and track 5).

Table 2 summarises the observed rip currents during the survey period. Although the average velocities are low, the peak velocities are high, as seen in the graphs. The peak velocities of rip currents up to 1.5ms^{-1} and 3ms^{-1} observed in Xai-Xai Beach are amongst the highest reported in the world (Leon *et al.*, 2008; Brander & Short 2000) and pose a risk to even the most experienced swimmer. Sabet & Barani (2011b), investigating rip currents along the southern coast of the Caspian Sea recorded rip currents with velocities up to 0.82 m s^{-1}. Linares *et al.* (2019) observed rip currents with speeds up to 0.9 m s^{-1}, induced by meteotsunami on southeastern beaches of Lake Michigan. Lee *et al.* (2016) observed rip currents with maximum speeds of 2.5 ms^{-1} in Haeundae Beach, South Korea. Scott *et al.* (2018) found flash rips up to 0.7 ms^{-1} in Bight of Benin coast, in Gulf of Guinea, West Africa.

The observed rip currents were located close to the reef gaps. This was noted earlier and explained by Leon *et al.* (2008) in field observations of reef rip currents on Yoshiwara Coast, Ishigakijima, Okinawa, Japan. They observed that during the ebb tide most of the water inside the beach lagoon was discharged through the reef gaps. Maia *et al.*, (2014), studying the spatial-temporal distribution of the rip currents in beaches of the municipalities of Cabo de Santo Agostinho, Jaboatão dos Guararapes and Recife in Pernambuco state, Brasil, found that there were high frequency and permanent rip currents associated with gaps in the reef. The rip currents that are observed on Xai-xai Beach may be classified as Channel rip currents, controlled by bathymetry, according to the classification presented by Castelle *et al.*, (2016) as they are induced by the reef. According to Brander (2018) Channel rips are a relatively well-documented and understood rip current type given their predictable location, allowing for relatively easy field measurements, and common occurrence worldwide. They can be relatively stationary over periods of days, weeks, and months. Their morphologic structure varies with channel depth and width. The strongest rip currents in Xai-xai Beach were observed in the northern beach, where the gaps in the reefs are located, suggesting an area of high-energy environment, and so not safe for swimming.

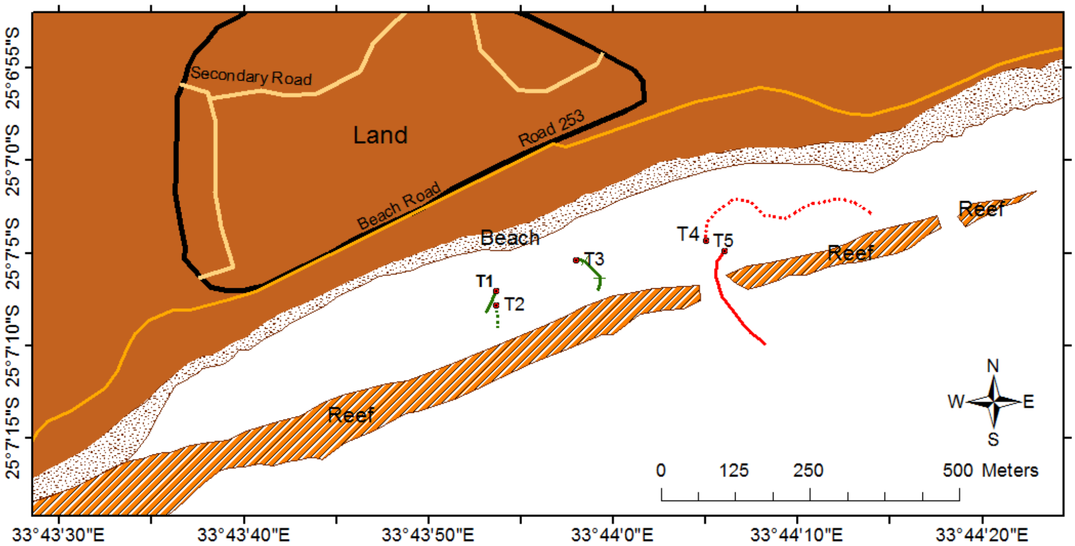

Figure 5. Rip current drifter tracks. The deployment points are indicated by the dots. Xai-Xai Beach, 8-18 March 2011.

Figura 5. Trajetórias de correntes de retorno. Os pontos de lançamento são indicados pelos pontos. Praia de Xai-xai, 8-18 de Março de 2011.

Figure 6. View of the rip currents across the reef gaps. Xai-Xai Beach, 8-18 March 2011.

Figura 6. Vista das correntes de retorno a atravessar o recife. Praia de Xai-xai, 8-18 de Março de 2011.

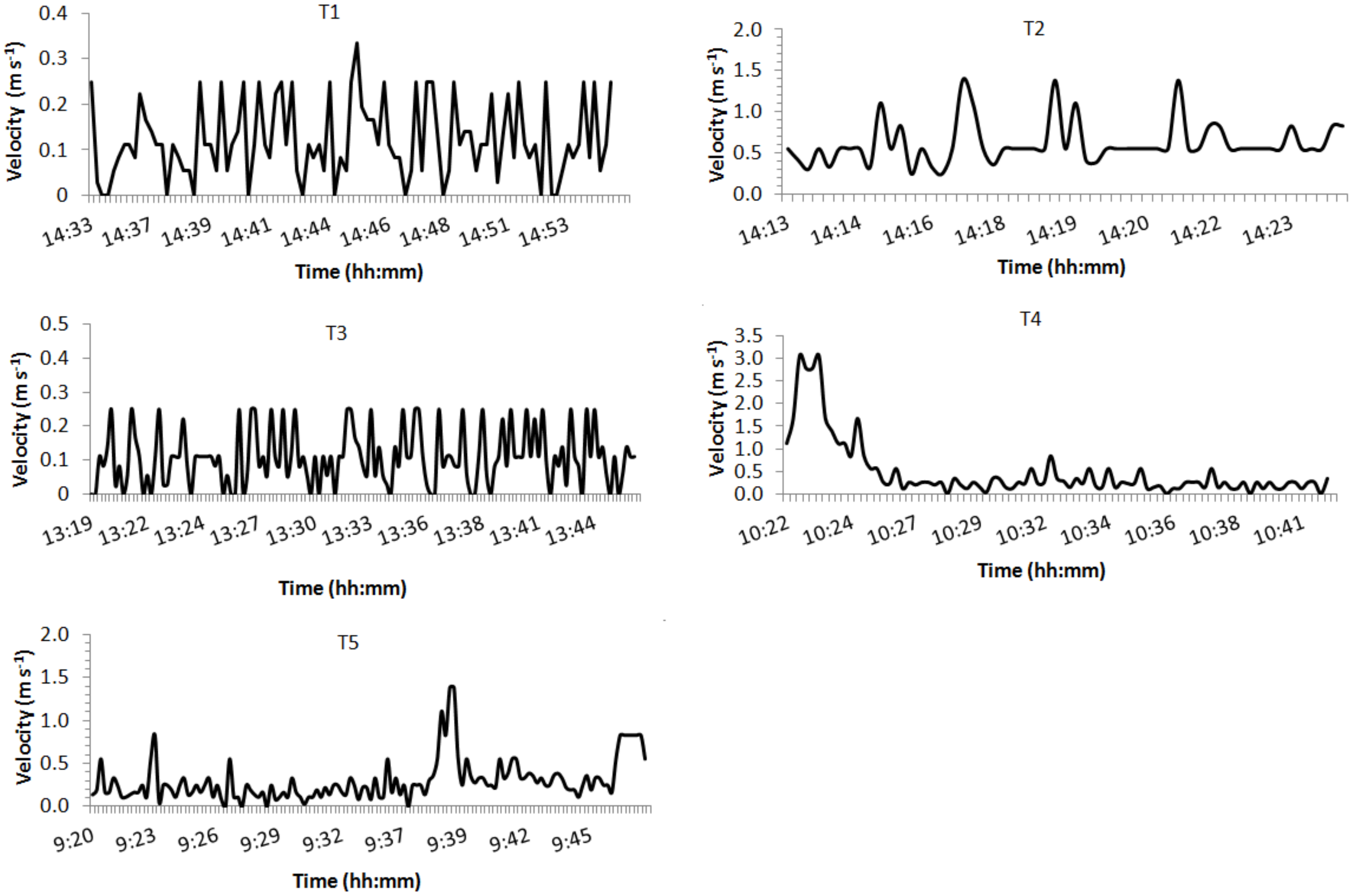

Figure 7. Time series of the rip current velocity. Xai-xai Beach, 8-18 March 2011.

Figura 7. Série temporal da velocidade de correntes de deriva litorânea. Praia de Xai-xai, 8 a 18 de Março 2011.

Table 2. Summary of the rip currents. Xai-Xai-Beaxh, 8-18 March 2011.

Tabela 2. Sumário das observações de correntes de correntes de retorno. Paria de Xai-Xai, 8 a 18 de Março 2011.

Track	Tide regime	Distance (m)	Period (s)	Average velocity (m s^{-1})
T1	Flooding Neap	126.8	1305	0.097
T2	Ebbing Neap	181.9	1650	0.110
T3	Flooding Neap	156.4	1665	0.094
T4	Ebbing Spring	461.1	1190	0.387
T5	Ebbing Spring	536.1	1700	0.315

4.3 Beach zoning

Based on the morphology, the Xai-xai Beach could be divided into two major areas, namely, the southern beach where the reef has no major gaps and the northern beach characterised by a few relatively wide gaps on the reef. Gaps in the reefs are the primary cause of the rip currents. Based on the occurrence and intensity of the rip currents, and considering the velocity threshold presented by Criado-Sudau *et al.* (2019) for zoning the Reserva Beach, in Rio de Janeiro city, Brazil, Xai-xai Beach could be divided into three major areas as follows: (i) the southern beach, characterised by a low-energy environment and weak currents (≤0.25 ms^{-1}), (ii) the mid beach, with medium strength currents and an incidence of weak rip currents, with velocity between 0.25 ms^{-1} and 0.5 ms^{-1} and (iii) the northern beach, characterised by a high-energy environment, with strong longshore currents and an incidence of strong rip currents (≥0.5 ms^{-1}). The southern beach is the safest place and hence recommended for swimming. The northern beach

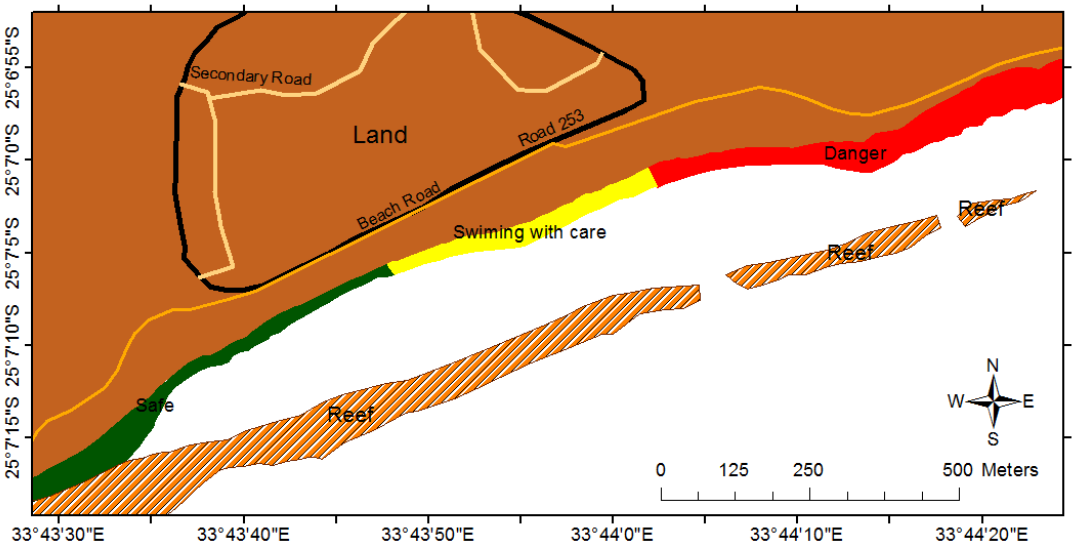

Figure 8. Proposed zoning of Xai-Xai Beach as to prevent hazards.

Figura 8. Proposta de zoneamento da praia de Xai-Xai para prevenir acidentes.

is the dangerous place and therefore, not recommended for swimming. In between, swimming could be allowed for experienced swimmers, though with caution. Figure 8 presents the suggested zoning of Xai-Xai Beach. Further, we strongly recommend the establishment of a flagging system and signals. Green flagging should be assigned to the southern beach, where swimming should be allowed. Yellow flagging should be assigned to the mid beach, where swimming should be allowed with caution and Red flagging should be assigned to the northern beach, where swimming should be prohibited. In addition, permanent lifeguard and beach assistant services should be put in place to provide timely assistance and rescue missions and reduce the danger.

5. CONCLUSIONS

Xai-Xai Beach, which is a lagoon like, about 2 km long, 200 m wide and 3 m average depth; protected from the ocean swell by a reef, oriented NE-SW direction, about 20 m wide and elevated 0.70 m above Mean Sea Level, with gaps along its extension, is one of the main attraction of tourists in the southern Mozambique. The beach receives on average 22,000 tourists per year. Despite the fact that the beach is protected from ocean waves, there are reports of casualties by drowning, on average 8-9 per year, threatening the thriving tourism.

In this research, drifters were deployed to investigate the nearshore currents in Xai-Xai beach. The drifters depicted the rip as well as longshore currents. The nearshore hydrodynamics was thought to be controlled by the reef. Unidirectional, northwards, longshore currents, with velocity up to 1.4 ms^{-1} and strong channel rip currents, with velocity up to 3.4 ms^{-1}, 5-10 m width and duration of less than 5 minutes, were observed. Strongest currents were observed in the northern end of the beach, were the main gaps in the reef are located. The study considers that the rip currents are the main threat to the beach users in Xai-Xai Beach.

Based on the strength of the nearshore currents, the beach was divided into three areas, namely: (i) the southern part, with weak currents ($\leq$0.25 ms^{-1}), classified as a "safe area", flagged green, and recommended for swimming; (ii) the northern part, with strong rip currents ($\geq$0.5 ms^{-1}), classified as a "hazardous area", flagged red, and prohibited for swimming; and (iii) the intermediate zone, with moderate currents ($\geq$0.25 ms^{-1} and $\leq$0.5 ms^{-1}), classified as a "moderate area" and flagged yellow, where swimming is allowed with caution. Further, the study recommends regular patrols by lifeguards and beach assistants during the peak tourism season, in summer, in order to reduce hazards.

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