Risk assessment of drowning incidents at Aksa Beach, Mumbai, India

Deepali Gadkari* and Subhankar Das

Department of Geography, University of Mumbai, Mumbai 400 098, India

The Aksa Beach is one of the most drowning incident-prone beaches in Mumbai, India. From 2006 through 2018, an average of 38 people drowned annually. A total of 445 non-fatal drowning victims have been rescued and 47 have died. No studies about these drowning incidents in Aksa Beach have been published. The incidences are classified according to various parameters such as season, tide time, lunar day, gender and age of victims, and locations on the beach to assess drowning hazards. The result is that both natural and demographic factors are responsible for drowning incidents. This study assesses the natural and social causes of drowning and suggests a prevention policy.

Keywords: Beaches, drowning hazard, moon phase, prevention policy, risk assessment, tide time.

DROWNING is a serious but less studied hazard that claims nearly 372,000 lives per year worldwide. More than 90% of these deaths occur in low- and middle-income countries[1]. Several thousand drowning incidents are caused by ocean water globally. However, these have not been given proper attention by the scientific community[2]. Drowning incidents occur on both the east and the west coasts of India. In Andhra Pradesh, more than 350 people lost their lives due to rip currents during 2000–10. Visakhapatnam has reported the highest number of drowning cases, around 293 between 2000 and 2010 (ref. 3). After Visakhapatnam, the Mumbai coast comes second with regard to drowning incidences. The Aksa Beach near Malad is one of the most drowning incident-prone beaches on the Mumbai coast. From 2006 to 2018, 492 drowning incidents have been reported at the beach. The number of victims due to drowning has increased significantly on Aksa Beach since 2006. We identified 15 locations on Aksa Beach where 252 incidents occurred; 45 died and 447 were rescued. The tidal channel to the south of the beach and the location opposite the Resort Hotel are the most vulnerable spots for drowning. The Aksa Beach is straight compared to the adjacent beaches. The area in front of the beach (towards the seaward side) shows accumulation of sand in the shape of bars and/or dunes. Some micro-geomorphic features exist, such as berms, runnels and ripple marks, despite the macro-geomorphic landform.

*For correspondence. (e-mail: gadkarideepali@gmail.com)

The Mumbai Fire Brigade Office has deployed lifeguards at Aksa Beach for safety purposes. The lifeguards maintain records of drowning incidences and send reports to the Fire Brigade Headquarters. In each shift, only three lifeguards are stationed at the beach, while there are more than 200 visitors during peak hours, especially in the afternoon. A CCTV camera has been installed at one location on the beach. However, live footage of the cameras is not available to the lifeguards who are on the field. A warning signboard is put only at the entrance and not all along the beach where the drowning incidents occur. Due to such insufficient measures, drowning incidences frequently occur along the beach. So far, hazard and risk assessment for drowning incidences for Aksa Beach has not been carried out.

Aim

This study aims to understand the nature of drowning hazards in relation to the tide and wave conditions and the hazard preparedness on Aksa Beach. The assessment of spatio-temporal distribution of drowning incidents and the relationship would be the main thrust of analysis to understand the nature of drowning hazards on Aksa Beach.

Study area

The Aksa Beach is located along the northern part of the Mumbai coast. The extent of the study area is between 19°10′38.19″N–19°12′28.19″N lat. and 72°47′41.88″E–72°48′21.88″E long. (Figure 1 *a*). The Beach is considered the most treacherous in the world[4]. It has a narrow width of 0.50 km and is 1.5 km in length. It is relatively straight than the adjacent beaches. The beach is sandy and smooth. The sandy backshore is bound by berms, embryonic sand dunes and marshy land (Figure 1 *b*). Sandbars are found parallel to the beach on the seaward side. Sandbars lead to devolve deep channels between the sand bars and the beach. The southern limit of the beach is marked by a tidal channel and to its south is a rocky shore platform. The Manori Creek marks its northern limit.

Data

For this study, both primary and secondary data were used. The primary data are related to beach morphology.

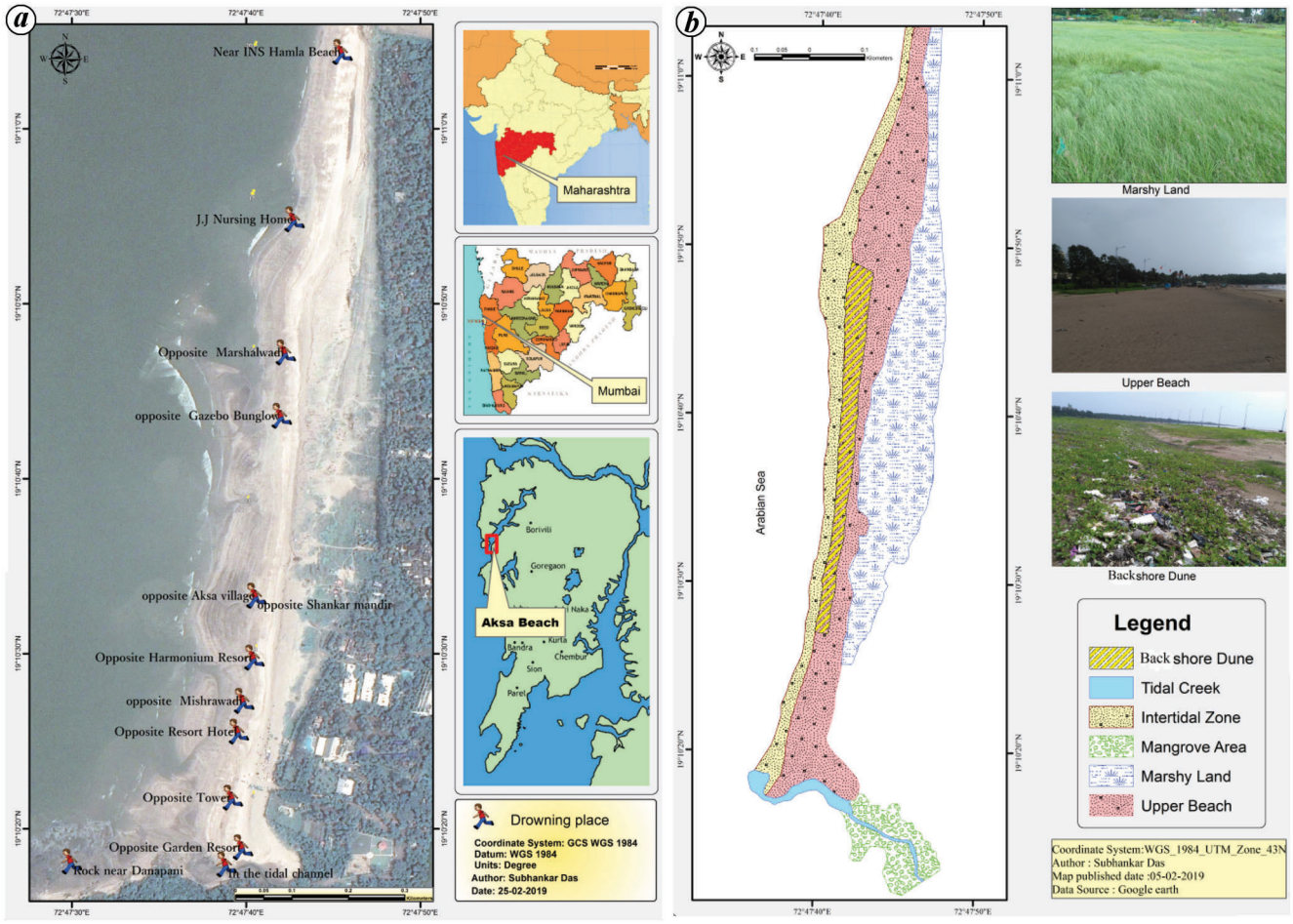

Figure 1. ***a***, Location map of Aksa Beach, Mumbai, India and location of drowning incidences, 2006–18. ***b***, Geomorphological map of Aksa Beach, 2018.

Secondary data include drowning incidents and historical tidal data. Data on drowning incidents are a key factor in this study. Table 1 provides details of the data used.

Methodology

Analysis of drowning data

Since 2006, lifeguards have been deployed at Aksa Beach. They maintain a detailed record of drowning incidents on the beach. These data have been collected from the Mumbai Fire Brigade Office at Byculla. This study also used data from national news agencies, daily newspapers, national on-line news websites and regional/local news websites to gather information on drowning incidents on Aksa Beach between January 2006 and December 2018. The drowning data included date and time, gender, age and the name of victims who died in a drowning incident. The data were compiled from the above-mentioned sources and carefully cross-checked with record data and newspaper information. The relevant data were extracted and filtered for unusual occurrences such as suicide. The date, time, exact location of the incident on the beach, number of victims, their age, gender and address were the main attributes of the incident. The geocoordinates of the locations were collected through a GPS survey. A digital database was generated by linking the attribute data to the spatial data. The data were statistically analysed – classified based on season, lunar days, weekdays, location, age and gender and graphs were plotted. The incidence distribution will help further analyse the background of beach morphology and morphodynamics.

Tide and lunar day data analysis

The oceanographic information complies with the Aksa Beach, which strongly influences the variability locality. The National Ocean Service, US has published ocean-wise tide data in pdf format. The data resolution is on a lunar day-basis. The lunar day-wise tide data were downloaded from 2008 to 2018 from the National Oceanic and Atmospheric Administration (NOAA) website. Tide height and lunar day were extracted according to drowning date from the whole downloaded data. The Rule of Twelfths was

Table 1. Details of data, type and sources

Data/variable	Type of data	Parameters/value	Source
Attribute data drowning incidents	Secondary	Number of victims Age Sex Accident time Accident location	Mumbai Fire Brigade Office
Tide height	Secondary	Tide height (m) with date and year	National Oceanic and Atmospheric Administration (NOAA; https://tidesandcurrents.noaa.gov/historic_tide_tables.html)
Lunar day	Secondary	Day of moon phase	NOAA; https://tidesandcurrents.noaa.gov/historic_tide_tables.html

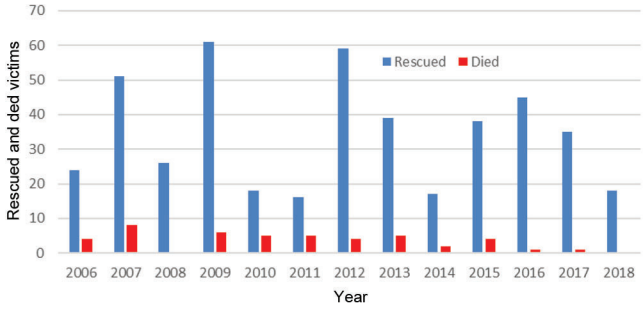

Figure 2. Year-by-year trends in drowning incidents and victims (2006–18).

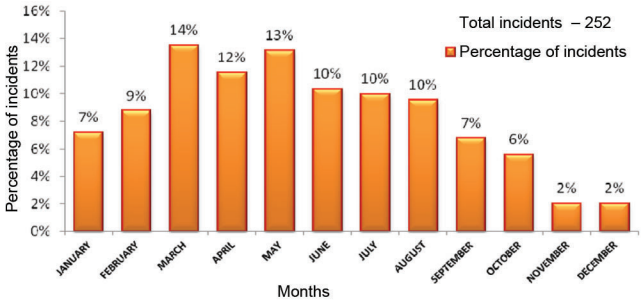

Figure 3. Distribution of drowning incidents across months (2006–18).

used to determine the exact tide height of each drowning incidence based on the time of the incident[5]. Tide heights (m) were reported in the range from 0.5 m to 5.1 m. The lunar day (e.g. Pratipada – the first day, Dwitiya – the second day, … Poornima/Amavasya (full moon/new moon day respectively, in the 15 days lunar cycle)) is identified according to incidental days from the Indian calendar. Tide height and lunar day are included in the database to determine the relation between drowning incidents and tidal conditions and lunar day.

Results

Temporal variations in drowning incidents

Results were analysed based on spatio-temporal drowning incidents and tidal data.

Figure 2 represents the year-wise distribution of drowning incidents over 13 years from 2006 to 2018 at Aksa Beach. Based on the data collected from the Mumbai Fire Brigade Office, the trends of incidents were not consistent, showing an increase in one year and a decline in the next year. Also, 252 drowning incidents occurred over these 13 years. An average of 19 incidents (8% of the total incidents from 2006 to 2018) occurred yearly. It may be noted that the maximum number of incidences occurred in 2007 (16%) and the minimum in 2018 (3%, which is just half of the average incidents per year).

From 2006 to 2018, 45 people died and 447 were rescued. There have been an average of three drowning deaths and 34 persons rescued annually. The highest percentage (18% of total) of drowning deaths occurred in 2007 and the second highest was in 2009.

Figure 3 depicts the month-wise distribution of incidents. Drowning incidents have occurred consistently throughout the years during all months. The highest number of incidents occurred during warmer months, particularly in the pre-monsoon season. A majority (39%) of incidents occurred from March to May.

Figure 4 shows that the maximum number of people drowned on Sundays (25.20%) and the lowest on Thursdays (8.33%). Also, higher drowning incidents (50%) occurred on weekends.

The time of drowning incidents varied throughout the study period, but mostly occurred in the afternoon between 12:00 and 6.00 pm with 175 incidents (70%), followed by the morning (between 6:00 and 12:00 am) with 52 incidents (21%). Only one incident occurred in the early morning from 2006 to 2018 (Figure 5).

Demographic variation in drowning incidents

A drowning incident that does not result in death is often called non-fatal drowning. Figure 6 shows that males had higher drowning rates than females. Males represented 80% of all drowning victims. Forty-five fatal drownings (died) and 447 non-fatal drownings (rescued) occurred in 13 years from 2006 to 2018. Out of 45 deaths, 38 were male and 7 were female. Of the 447 non-fatal drownings, 363 were male and 84 were female. The maximum number of drowning victims were youth (aged 15–30 years, almost 65% of the total), both male and female. The highest proportion (40%) of drowning victims was in the age group

of 15–20 years, while 25% of drownings occurred among young people aged 20–24 years. The lowest drowning rate (15%) is found amongst middle-aged adults (35–59 years), senior citizens (age > 60 years) and also kids (age group of 5 to 10 years). Though this is so, kids do become victims of drowning. The most common reason for child drowning incidents was a lack of adult supervision[6]. In terms of age, older children performed risk-taking activities that may have overestimated their physical skills and performance in relation to physical strength and experience[7].

Spatial distribution of drowning incidents

Figure 7 shows the spatial distribution of incidents and drowned victims along Aksa Beach. There are 15 drowning locations where 252 incidents have occurred between 2006 and 2018; 45 died and 447 were rescued. The location opposite Resort Hotel recorded the highest number of accidents, including those who drowned. In contrast, the location opposite Gazebo Bungalow had the lowest, only once during the last 13 years. The number of incidents and drowned people was 71 and 139 respectively, at the location opposite Resort Hotel. This and other locations such as the stream at the southern end of the beach, opposite Aksa village, opposite the tower and Danapani (south of Aksa Beach) locations, are on the top list for drowning incidents (Figure 7). On the other hand, Hamla Beach, Marve Beach, the location opposite Harmonium Resort and Mishrawadi village have reported rare incidents of drowning.

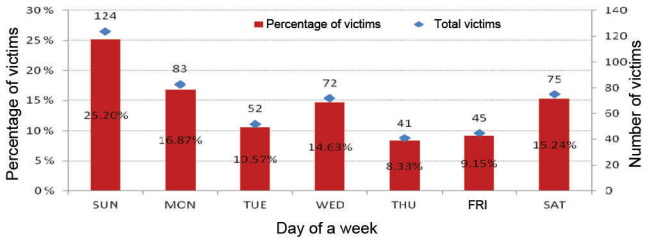

Figure 4. Number of victims by day of the week (total and percentage of victims, 2006–18).

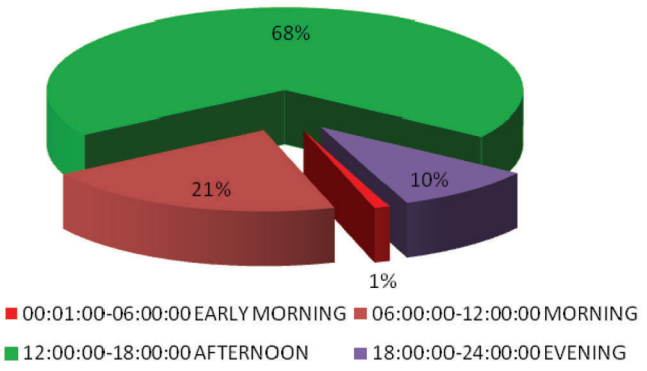

Figure 5. Time of day and percentage of drowning incidents.

Tidal regime and drowning incidents

Tidal data have been classified into micromareal, mesomareal and macromareal tidal water levels following the method of Masselink and Short[8]. Drowning incidence data is obtained from the Brihanmumbai Municipal Corporation (BMC) and is further analysed for drowning risk assessment at the Aksa Beach. The time and height of the high tide on the days of the incidents were identified by NOAA. Based on these two datasets, the height of the tide at the

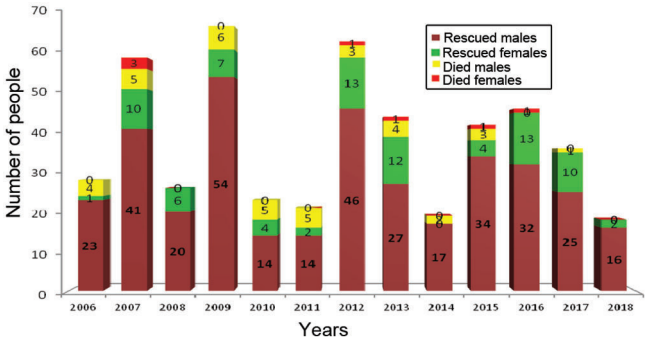

Figure 6. Drowning victims classified by gender (fatal and non-fatal, 2006–18).

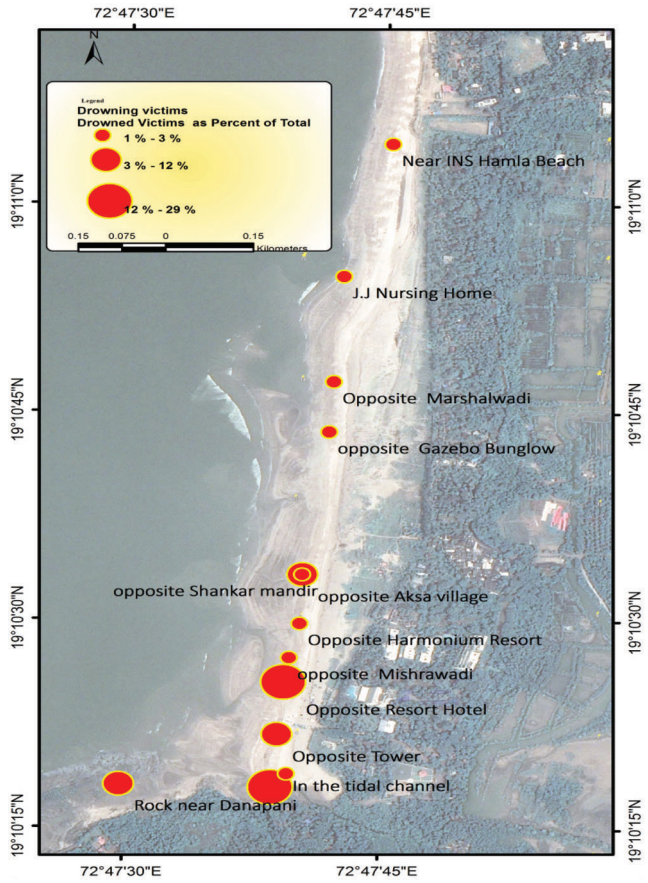

Figure 7. Percentage of total drowning victims by location.

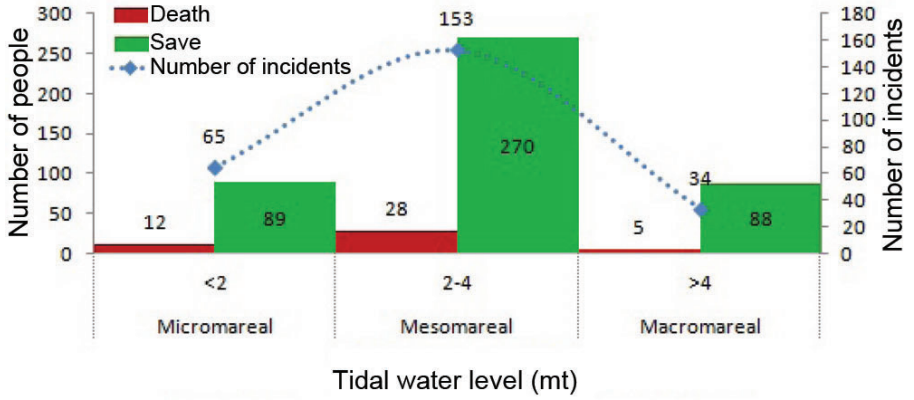

Figure 8. Drowning incidents and drowned victims by tidal water levels.

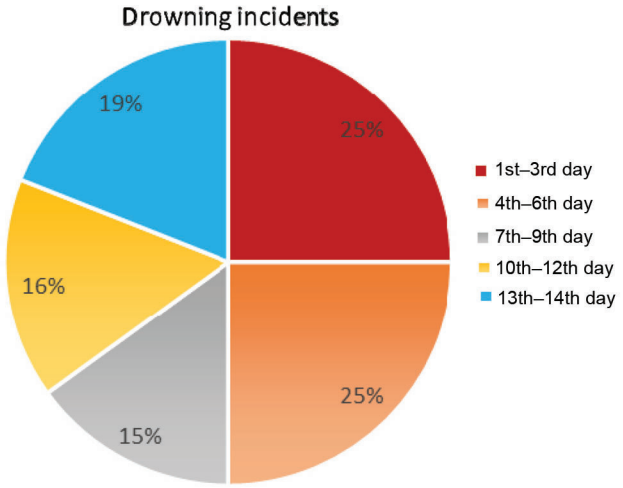

Figure 9. Coastal drowning by phase of the moon.

time of a drowning incident was computed and the frequency of drowning incidents in each tidal range was plotted (Figure 8).

Moon phase and drowning incidents

Figure 9 shows a pictorial association between drowning incidents and the phase of the moon. The frequency of incidents was maximum during the first to sixth lunar days before or after the full moon or new moon. It was nearly 50% of the total. The drowning frequency increased two days before and three days after the full moon or new moon day[3]. While considering only the spring tidal stage, the relative rip current drownings were recorded high on either side of the spring tide (two days before and up to three days after).

Discussion

The maximum number of incidents (13%) occurred in March over the study period. Winter was the season with the lowest incidents, whereas pre-monsoon was the highest. There are two reasons for increased drowning incidents during the pre-monsoon season. The first is rough sea conditions (tidal danger, strong current, low pressure and high wind). The second is the increased number of visitors due to the summer break in academic institutions.

During a given week, drowning (17%) is more likely to happen on a Monday than on a Saturday (15%). This is due to increased number of visitors to the beach during long weekends and holidays. The number of drowning victims shows a positive correlation between the occurrence of drowning incidents and the number of beachgoers, which is low on working days, medium on Wednesday and very high from Saturday to Monday.

The peak hour of incidents was from 12:00 noon to 6:00 pm. This is because most people visit the beach during this time for various activities like swimming, bathing, playing ball and rock climbing.

Male victims were more vulnerable due to their illogical masculine behaviour than females[9]. Men probably underestimate natural oceanic conditions like wave height, tide conditions and current patterns. They also tend to overestimate their swimming ability and take more risks than women[10]. Alcohol drinking is one of the most important causes of incidents for male victims because men drink more alcohol than women near the beach waters during bathing[9,10].

In this study, we also found that the reason for more victims in the age group of 15–30 years, though this age group is mentally and physically fit and independent, is that they tend to take more risk than smaller kids and older people[7,11,12].

Most of the incidents occurred in the mesomareal tidal regime (2–4 m height) at high tide. Another important observation was that drowning incident (drowning and death) occurred even at low tide conditions when the tide range was less than 2 m (refs 3, 13). This suggests that the tidal stage plays a vital role in generating rip current. The mid–low tide time during the day may have the strongest rip currents[14–18]. More people will go surfing during low tide and therefore are more exposed to rip currents. Therefore,

the tidal stage of the moon phase plays a significant role in the drowning incidents.

Nearshore drowning hazards are on the increase with increasing beach tourism. Drowning is one of the neglected hazards for prevention and management. Multisectoral collaboration among Government, NGOs, the healthcare sector, researchers, media, industry and civil society groups is crucial for the prevention of drowning at local, regional and national levels. Based on the analysis of data, observations and discussions with stakeholders at the beach, we suggest the following measures to reduce the number of drowning incidents.

National plan to keep people from drowning in water

A national beach safety (or drowning prevention) plan should be drafted consisting of fundamental concepts, objectives, activities and coordination mechanisms for reducing/avoiding fatal and non-fatal drowning. It is suggested to include the following in such a plan.

Signage: This is also a frequently recommended prevention strategy. Aquatic safety signs alert beach users about the type of hazards, dangerous locations on the beach, submerged dangerous rocky structures, etc. Only a few caution signage flags are placed at the entry of Aksa Beach, but not on the entire beach and the locations where accidents generally occur. So enough warning signage should be put along the beach to alter the beachgoers.

Life jackets: A lifejacket plays a significant role in the prevention of coastal drowning. A few lifejackets are kept in the cabin of the lifeguards for their own use and not for visitors. It is recommended that there should be enough lifejackets available for the beachgoers. Use of lifejacket should be made compulsory for the beachgoers who intend to swim in the near-shore area.

Lifeguards and equipment

Only three lifeguards are employed in each shift on Aksa Beach. Considering the number of visitors, particularly swimmers, this number is not sufficient. Each shift will require a minimum of six lifeguards with modern rescue equipment on a normal day (the approximate number of visitors is 200 per hour). Approximately ten lifeguards should be on duty over the weekend, summer vacation and other public holidays (the approximate number of visitors is 300 per hour).

Camera: On Aksa Beach, only one live camera has been installed. However, lifeguards who patrol the beach do not have access to live footage. Therefore, they should have access to live footage for proper supervision and to detect incidents in real-time to rescue and prevent drowning.

First aid/paramedical facilities: Sometimes, there is a need to hospitalize victims. Lifeguards should be well-trained in CPR (cardiopulmonary resuscitation), which can save the lives of rescued victims. It is a 10 km drive from Aksa Beach to the nearest Malad Hospital. As a result, most rescued victims pass out on the way to the hospital. Hence there should be an ambulance, particularly dedicated to the Aksa Beach with paramedical facilities.

Strengthening public awareness of drowning through communications

Public awareness and behaviour change campaigns are crucial if drowning prevention measures are to be successful. Public awareness should include knowledge of the hidden risk factors of the natural condition of the beach environment (like local beach bathymetry, morphology, waves and rocky platform). Such information should be put up on the beach. Beachgoers should be allowed to swim between the signage on the beaches patrolled by lifeguards. Indeed, many people are unaware that drowning is a major problem. Therefore, strategic communication should be incorporated into the planning phase of all interventions.

Conclusion

We have studied the spatio-temporal distribution of drowning incidents (from 2006 to 18) at Aksa Beach, Mumbai. The relationship between the drowning incidents and factors such as season, tide cycle, lunar day, day of the week, age and gender of victims, and local geomorphic features on the beach was assessed. Among these, local scale morphology is essential, followed by the tidal cycle, lunar cycle, location within the beach and season (month of the year). Young adult males were more vulnerable to drowning incidents. There are studies on drowning hazard analysis in the country. Thus advanced research on the management, mitigation of incidents, changes in morphology and hydrodynamics is required.

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