Surf zone-related drownings and injuries based on lifeguard records in Goa beaches (2008-2020)

Ch Venkateswarlu
Andhra University Department of Meteorology and Oceanography
Arun Kumar Surisetty V V (arunocean@gmail.com)
Space Applications Centre https://orcid.org/0000-0002-7100-5170
Ankit Somani
Drishti Marine
B. Gireesh
Andhra University Department of Meteorology and Oceanography
C V Naidu
Andhra University Department of Meteorology and Oceanography

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Abstract

The study is based on lifeguard data from 44 Goa beaches over a period of 2008–2020. Calangute reported the highest Surf Zone Injury (SZI) cases with 24.63% followed by Baga and Candolim in the north Goa. In South Goa, Colva recorded the highest percentage of beach victims with 18.25%. Since, Goa beaches are world-famous, many tourists from foreign countries have become victims with a total percentage of 22.2%, thereby showing its importance to the global community. Out of all Indian states, Karnataka recorded nearly 21.93% cases as compared to Goa with 13.53%. Since, there is a stringent lifeguard system available at Goa beaches, the drowning percentage is just 2.86%. Rips are found to be the primary cause responsible for most cases accounting for 59.32% with nearly 3030 victims. The secondary cause is due to shore breaking. The most common injury type is a fracture of the legs which accounts for 8.02%. Apart from rip current related cases, there are other cases reported due to tourism activities. Out of all recreational activities, wading resulted in more number of SZIs with 19.61% followed by surfing and body boarding. The SZI-related cases have also been examined based on age and gender. The predominant age group involved in the injuries was between 19–25 years (36.33%) with the majority of victims being males (78.59%). These details give an idea of which regions along the beaches, management has to focus on and restrict the zones from any kind of recreational activities. This analysis is the first of its kind in India, where a detailed study is carried on based on lifeguard reports, suggesting the importance of rescue or drowning data.

1. Introduction

In recent years many coastal regions are developed for the urbanization, social activities commercial purposes, cultural activities, and tourism, etc. Nearly half of the world's population lives within 200 km of the coastal regions and these numbers are probable to increase double in 2025 (Ferrari et al. 2019). Coastal areas represent an important source of the economy worldwide (Jiménez et al. 2007). Sandy beaches are beautiful, popular for recreation, and widely connected to tourism cultural initiatives and therefore millions of people visit every year (Arun Kumar and Prasad 2014; Castelle et al. 2018). However, beachgoers are unaware or unskilled of oceanic processes that take place in the nearshore and therefore resulting in surf beach dangers (Puleo et al. 2016). In general, the public represents a diverse demographic and visits beaches for a variety of recreational activities including sunbathing, wading, bodyboarding, swimming, and surfing (Niels West 2005; Castelle et al. 2018). However, beaches although attractive, can sometimes also be the dangerous environments. The beaches are characterized by powerful wave breaking and currents in the surf zone, which can become dangerous when beachgoers enter in the surf zone water (Short and Brander 2014; Castelle et al. 2016, 2018; Short and Weir 2018) leading to many surf zone injuries and even drownings.

Surf zone Injuries (SZIs) are mainly affected by two reasons i) Rip currents and ii) Shore break waves resulting in spine, neck, and shoulder dislocations (de Korte et al. 2021). It is well established that the primary cause of these fatal and non-fatal drowning incidents is due to rip currents on sandy beaches. Rip currents are strong and narrow flow of water, frequently originate close to the shoreline, and generally flows towards offshore (MacMahan et al. 2006; Dalrymple et al. 2011; Castelle et al. 2016, 2020). On the sandy beaches, different types of rip currents can occur (Castelle et al. 2016) but one of the most important and commonly understood types is *Channel rips*. They occupy morphologic depressions between sandbars and produced by variation in the wave breaking (Castelle et al. 2016; Pitman et al. 2021). Rips currents generally flow toward the sea with a distinctive mean velocity of 0.5–0.8 ms^{-1} and sometimes occasionally with magnitudes reaching 2 ms^{-1} (MacMahan et al. 2006; Pitman et al. 2021). Rip currents hazards are widely studied as Surf zone injuries as compared to the shore break wave hazard. Shore break waves can cause a large number of injuries including spine, neck, and shoulder dislocations (Robles 2006; Puleo et al. 2016). On some beaches, shore break waves may also be a primary cause of Surf zone Injuries (SZIs). For e.g., shore break waves results up to 80% of the total SZI at Ocean City Maryland (Muller 2018; de Korte et al. 2021). However, the probability of rip current drownings or beach hazards also depends on multiple social factors such as the presence/absence of lifeguards, choosing the swimming location, behavior of the beachgoer, and their knowledge of rip currents. (Gilchrist and Branche 2018; Ménard et al. 2018). There are many programs and interventions on rip currents around the globe to reduce the social aspects of rip current drownings. Lifeguards are established as the most effective method for saving the people from the drowning incidents on popular beaches. Recently many numbers of dedicated international campaigns have focused particularly on rip currents interventions. For example, the "US break the Grip of the Rip" campaign (https://www.weather.gov/safety/ripcurrent), founded in 2005, mainly focus on how to identify the rips, and how to escape the rips, and why they are dangerous (2005). In Australia, most campaigns from 2009 onwards have been focused on how to avoid and identify rip currents, and recently adopted the "*Think Line*" (https://www.beachsafe.org.au/surf-safety/rip currents), there is a "*Respect the Water*" campaign in the UK (https://www.respectthewater.com), which is more extensive on raising awareness of the dangers represented with coastal or marine recreation. New Zealand has recently launched the three R's ("*Relax, Raise, Ride*") rip current campaign (http://www.findabeach.co.nz/besafe/hazards/ rips) (Pitman et al. 2021).

In the case of India, the country is blessed with 7600 km of beautiful coastline with the majority of sandy beaches. Each state has a few unique beaches, which are popular for beach recreation. Goa is such a state, where majority of the revenue is from the tourism industry and the beaches are the backbones. It is one of the richest states in India, with two- and half-times highest GDP larger than over the country, tourism is the primary financial aspect to grow the GDP. Situated in the western part of India with a 160 km long coastline, Goa has two-thirds of the most attractive and recreational sandy beaches in India. The expansive structure of these beaches attracts thousands of foreign and local tourists, for water sports activities such as surfing swimming, wading, etc. Occasionally, surf sinking is reported in some areas of the beach (Chandramohan et al. 1997). Drishti Lifesaving Ltd. (undertaken by the Department of Tourism, Government of Goa) is a professional organization that provides lifeguard

services on Goa beaches and interior waterfalls. Over 700 trained lifeguards have been deployed to provide dedicated services across every beach in Goa. Additionally, the Beach Safety Patrol focus on women's safety, assists tourists and deters tourists from venturing into the sea. The service has led to a 99% reduction in deaths due to drowning and significantly improved the tourist experience in Goa. Over 3,000 lives have been saved due to intervention rescue operations. (https://www.drishtimarine.com/).

2. Study Area

2.1 Regional Settings

Goa is a small state located along the western part of India, with two districts, North Goa and South Goa, covering an area of around 3702 km^2. It lies between the latitudes 14°53'54" N and 15°40'00" N and longitudes 73°40'33" E and 74°20'13" E. It has about 160 km of long coastline, with estuaries, sea hills, promontories, pocket beaches, dunes, hard rock wave-cut platforms, and world-famous beaches, etc. The oceanic climate of Goa dominates over three seasons (1) southwest monsoon (June to September); (2) northeast monsoon (October to January) and (3) the fair-weather period (February to May). It experiences a tropical humid climate and receives rainfall from southwest monsoon winds from June to September. The annual rainfall ranges from 250 to 300 cm in this region, while temperature varies between 20 and 37° C. The sea conditions are generally rough during the southwest monsoon and calm during the rest of the year (Chandramohan et al. 1997). There are around 44 beaches in Goa out of which18 beaches are there in North Goa and 26 beaches in South Goa. Mainly 20 beaches are famous for the tourism industry.

*[*Figure 1 *near here]*

3. Data And Methodology

Figure 1 shows the beach locations used for data collection, where lifeguards are deployed round the clock to prevent and protect the beachgoers from the drowning risk. Surf zone injuries (SZI) data were collected and maintained by Drishti Lifesaving Pvt. Ltd. (*hereafter* DLPL), which provides professional lifeguard services on behalf of the Department of Tourism, Goa. Unlike other countries, where lifeguards are usually deployed only during the peak tourist season, Goa beaches are patrolled throughout the year. The beaches are patrolled both north and south of the bathing area, although those regions are restricted for swimming. The bathing zone is generally located on a shore-connected shoal, where waves break and typically away from the rip channels. All the beaches are patrolled using four-wheel drive jeeps from 6 AM to sunset (depending upon the season) although lifeguards are present throughout the day even after patrolled hours. All beaches are closed for any kind of bathing or swimming activity during rough sea state conditions associated with storms or monsoon.

Firstly, the SZIs data were checked and corrected for any errors and anomalies (da FKlein 2003). For example, there were at times data appeared in twice at the same time, and in other cases gaps were found. All the data related to SZIs were carefully reviewed and corrected for any such anomalies (Brewster et al. 2019). The drowning data includes injury/accident date**,** time of injury, gender, age, nationality, cause of injury, health conditions (e.g., conscious and unconscious), location of the incident (e.g., swim zone, non-swim zone, beach operation status etc.), cause (e.g., rip currents, shore-break waves etc.) and injury analysis (e.g., spinal injury, cervical strain, dislocated shoulder), body region (e.g., lower extremity, upper extremity, face), displacement (e.g., sent home, call to ambulance, admit, sent to hospital), incident leading to injury (e.g., thrown on surf, wave, tide, hit by body board), activity type (e.g., wading, surfing, boarding, watersports and etc.).

Lifeguards patrol the entire beach and define some places with strict restrictions like bathing and swimming prohibition etc. (de Korte et al. 2021). Some beaches along this coastline have totally unrestricted areas. Lifeguards are responsible for the implementation of the surf rescue and beach regulations. They are responsible for medical emergencies and for providing medical first aid before ambulance or medical services arrive at the beach. During the patrolling time, they hoist flags within 10 m with different combinations of colors indicating level of the risk (1) the green flag - safe and swim area with lifeguard on-duty, (2) yellow and orange flags - dangerous for bathing, but monitored and (3) red flag - swimming strictly prohibited, where the danger could be due to rough sea conditions, submerged rocks, submerged hazardous objects, area prone to the formation of rip currents, sudden drop in seafloor depth, presence of harmful marine creatures, etc. They are sometimes hoisted due to pollution in the waters or lightning, which could be harmful to the beach users. Whenever there is a medical incident on the beach, the lifeguards respond to the scene by providing the care and assisting with paramedics.

The Chief lifeguard is responsible for verifying the incident, including patient information and surf conditions at the time of the incident, and reporting to the higher authority in an appropriate format. When an incident occurs, a report will be generated by the lifeguard on duty in a prescribed format (Figure 2) and are sent to the headquarters for compilation. In contrast to the SZI report from other countries, rip currents are not pre-defined as an incident cause. Instead, those incidents are deduced from the detailed comments provided in the "Details of the Incident and Casualty type" where the beach user was caught in the rip current mentioned explicitly. Arun Kumar and Prasad (2014) used a similar strategy for getting rip current related incidents from Police First Information Reports (FIRs) to generate a database. Since 2018, DLSL started recording rip currents incidents exclusively in a separate column along with the approximate location on the beach. This would enable the beach managers to take preventive actions against such dangers in the future and could able to identify the rip current hotspots.

The variables from the lifeguard logs are scrutinized as follows: date, location of the beach (beach name), incident starting time, incident ending time, flag colors, swimming zone or non-swimming zone, age, gender, nationality of the victim(s) with full postal address, activity (watersports, wading, swimming, surfing, and bodyboarding, etc.), cause of injury (rip current, tide, shore break, suddenly wave attack to falling the water, and others), type of injury (sinking, injury/ contusion, spine/cervix, break the bones/luxation and, etc.). Sometimes, when the lifeguards are absent, the beach in operation that time will be closed to beachgoers. The drowning phase is presented according to a 4-step classification, ranging from mild to very severe: (1) fatigue, but no sign of water aspiration, (2) moderate respiratory weakness or anxiety, (3) altered consciousness, severe respiratory failure, or severe pulmonary edema, tachycardia or hypotension and (4) coma, respiratory or cardiac arrest (Castelle et al. 2020). The total data used in this work was gathered over a total of 40 Goa beaches between October 2008 and March 2020. North Goa consists of 16 patrolled beaches whereas South Goa has 24 beaches. A total of 4837 injury data were reported during the study period (please refer to Tables 1 and 2). Partially filled forms and the reports without proper formatting are discarded from the study in order to avoid confusion.

[Figure 2 near here]

4. Results And Discussions

Yearly, a large number of beachgoers visit popular beaches in north Goa viz., Baga, Calangute, Candolim, Arambol, etc., and eventually higher number of SZI cases were reported (n = 775) with around 24.63% from Calangute, 23.39 % (n = 736) from Baga and 12.01% (n = 378) from Candolim. Whereas, in South Goa, highest percentage of beach victims are from Colva with 18.25 % (n = 327), followed by Palolem 14.21% (n = 251) and Benaulim 10.34% (n = 179). A detailed statistical analysis was performed on the data to capture the main features of surf zone-related incidents and events, in particular, to understand the relationship between SZI and individuals.

[Figure 3 near here]

Goa beaches are mostly visited by foreign tourists apart from the Indian tourists throughout the year. The spatial distribution of surf zone injuries that happened on these beaches during the study period are plotted according to the victim's address (state/country) in Figure 3 (a & b). Out of all the victims, Indians were 77.3 % (n = 3807) and foreigners were 22.2 % (n = 1095). It has been observed that victims from Karnataka account for the highest number of SZIs with 21.93% (n = 835), which could be due to its close proximity to Goa beaches, followed by Maharasthra 19.41% (n = 739), Goa 13.53% (n = 515) and Delhi 5.17 % (n = 212). Most of the victims from foreign countries belong to Russia, England, Australia and the United States. Although the study seems to be regional pertaining to a few beaches in Goa, due to its popularity across the world, many foreign people who visit the beaches fall victims to the surf zone hazards, particularly the rip currents.

[Table 1 near here]

[Table 2 near here]

[Figure 4 near here]

Figure 5 provides an overview of SZI types including primary cause, injury type, and activity of the beachgoer at the time of the incident. Deaths due to drowning only covers 2.86% of the injuries (Figure a). It has been found that the primary cause of the SZIs is due to rip currents totaling around 59.32% (n = 1948) incidents and 61.50% (n = 3030) victims. Males contribute to nearly 48.63 % of (n = 2396), a large portion as compared to females (12.87%; n = 634) (Figure 5). Followed by rip currents, another primary cause was due to shore break accidents in crowded bathing zones, which contribute to around 12.22 % (n = 602) male, 3.43 % (n = 169) female. Wave attack is relatively less, where males contribute to 4.99% (n = 246) and 1.93% n = 95) by females. There were a greater number of incidents when the people venturing into the surf zone become panicked and leading to health issues like heart attack etc. They contributed to nearly 8.30% (n = 409) males and 1.99 % (n = 98) females. Around 2.86% (n = 141) dead bodies were recovered during the study period with around 2.39% (n = 118) were males and 0.47% (n = 23) were females.

Apart from the beachgoers who are comforted and released after rescues, the majority of around 19.97% were admitted to the hospital. The most common injury type is a fracture of the legs (8.02%) followed by injuries in bones, spinal or bleeding (4.38%), and knee injuries (4.2%). Several other injuries like a neck injury, small wounds, and pains were also reported, which did not require any further medical assistance. Apart from rip currents and accidents during recreation, shore-break waves are the important cause of SZIs (6.92%, Figure 5a), which would have increased the risk with beachgoers doing wading, bodyboarding and surfing. Getting panic (10.29%) is one of the major causes of the rescue either when a people get in a rip current or involved in any other beach activity. This shows that most of the people are unaware about the hazards posed in the beaches. The hazard would become even danger when the beachgoer is drunken. Around 18.65% of beachgoers were in a drunken state when a rescue happened.

Figure 5c shows a large proportion of surf zone injuries are related to wading (19.61%), surfing (14.21%), and bodyboarding (9.78%) activities as evidenced by the large proportion of knee injuries, neck injuries, bleeding, etc. Wading is primarily responsible for a greater number of cases with around 26.95% (n = 885) and around 19.61% (n= 966) victims were befallen. Out of these, 12.60 % (n = 621) were men and 7.0% (n = 345) were women. Due to a large number of people entering the surf in a drunken condition, the SZIs are more recorded when the victims were in a drunken

state. Around 23.11% (n = 759) incidents with 18.65% (n = 919) victims were recorded. Very few females were observed in this condition with 1.22% (n=60) but a large proportion is from males 17.43% (n = 859). Although surfing is uncommon in Goa beaches, surfing incidents contribute to around 18.36% (n = 603) with 14.21% (n = 700) victims. Bodyboarding also contributes around 10.87% (n = 357) incidents with 9.78% (n = 482) victims. Accidents due to water sports activities are very minimal, where around 6.52% (n = 214) incidents with 6.39% (n = 315) victims were observed. It represents that the water sports activities take much care during the operations. However, despite of such care, some incidents might happen due to unknown or unforeseen reasons (Brighton et al. 2013). Other activities include rock/ cliff-related, rather than fishing and scuba diving, which are although relatively high but uncommon at every place. This analysis is however limited to non-conclusive analysis due to certain data gaps. Table 3 provides more insight into the drowning population and shows that there is a large majority (74.1%; n = 33) of males involved in severe drowning incidents (stages 3 and 4), while milder drowning incidents (stages 1 and 2) are approximately equally distributed between males and females. Overall, 79% (n = 222) of the drowning incidents are caused by rip currents, a proportion that ranges from 50 to 82% depending on the drowning stage (Table 3).

[Table 3 near here]

[Figure 5 near here]

Figure 5 show the primary cause, injury type and activities of a beach goer at the time of the incident reported. The majority common type of SZI is comforted/ released 48.75 % (total n = 2402) victims, and 37.83% (n = 1864) men, 10.92 % (n = 538) women, followed by illness/ hospital 19.97% (n = 984) victims 16.18 % (n = 797) men, 3.80% (n = 187) women, fracture of legs 8.02 % (n =395) victims, and 6.15 %(n = 303) men, 1.87% (n = 92) women, bones/spinal/bleeding victims were 4.38 % (n = 216), 3.63% (n = 179) men, 0.75% (n = 37) women. 4.20% (n = 207) knee injury victims were found, in 3.11% (n = 153) of men, 1.10% (n = 54) women were identified. Suspected neck injury counts were identified 4.95% (n = 244), 3.94% (n = 194) of men, 1.01% (n = 50) women. Bandage / wound 4.08% (n = 201) victims, 3.31 % (n = 163) men, 0.77% (n = 38) women. Rip currents are the major cause for the surf zone rescues contributing to nearly 2380 males and nearly 620 females. Drunken males (n = 823) contributed to maximum number of cases as compared to females (n = 25). Few of beachgoers needed first aid with 8.10% (n = 399) out of which, 6.45% (n = 318) were the men, 1.64% (n = 81) were the women. Coming to total drowning incidents of 6.05 % (n = 298), 5.32 % (n= = 262) were the men, 0.73% (n = 36) were the women. Maximum beachgoers were in conscious state when they were rescued, which is around 87.31 % (n = 4302) victims. Few of the data were missing when an incident happened. Data missing means, they were recorded the incident but no information of the victims were made available, such data were discarded from the analysis.

[Figure 6 near here]

The predominant age group involved in the surf zone incidents was between 19-25 years (36.33%), with the majority of victims involving males (78.59%), whereas females comprise of 20.85%. Figure 6 shows the age-wise distribution of the surf zone incidents for the entire dataset. The distribution for any specific activity like surfing, wading, etc., or the injury caused by wave attack, rip currents, etc., and even major incidents like spinal/bone injuries are shown in other panels in Figure 6. However, the distribution of age group within gender was non-normal, injured females are more than males within 0-18 and 36-60 group and less than males within 19-35 age. Out of these, females were injured on around 30 % were between 19- and 25-years age, 28.98 % (26-35 years), followed by 11.16 % (36-45 years), and so on. This suggests that the female youth between 19 and 35 are becoming more prone to the surf zone danger. This could be either due to negligence in following appropriate surf zone behavior while venturing into the sea, or unaware of such dangers, or less skilled in handling such hazards (McCool et al. 2008).

The median and mean ages from the dataset were 27 (19) and 30 (26) years for males (females), respectively. Same age and gender distributions are observed for surfing activity (Figure 6b) for the ages between 0 and18 years. Wading is mostly done by females of age 13-25 years. The wave attack/shore break-related injuries are more in males for ages 19-25 and females for ages 26-35, 60+. In contrast, the population injured due to rip currents is younger with 66% within the age group 19-25, followed by 26-45 years. The spine injury people are also observed within 19-25 years, which is almost similar to wading injuries. The drowning people are high within the age group 46-60 years followed by 19-35 years. Only male children were drowned within the age 0-12 years. The percentage of injuries in the non-swim zone is seen more in males of age 19-25 years. Still around 10% of children (0-12 years) were injured in the non-swim zone. Most of the incidents were happened in the non-swim zone with around 1370 (41.72 %) cases and nearly 1939 (39.35%) victims were suffered. Out of these 31.22 % (n = 1538) were men, 8.14 % (n = 401) were women (Figure 7).

[Figure 7 near here]

Non-swim zones are often identified by the Lifeguard on duty as most dangerous for bathing for any kind of activity and are usually restricted. Non-swim zones are often consisting of dangerous and sharp or slippery rocks, sudden changes in the depth persistent for many days, or any marine animal hazard. These zones are identified every day by the lifeguards and flagged appropriately. However, some people do not follow the lifeguard's advice and get into trouble. On the other hand, swim zones are not categorized as safe zones. They are otherwise, well known and monitored by a team of lifeguards. These zones are relatively near to the beach entrance and occupied by many beachgoers in general. In the swim zone, around 1302 (26.43%) incidents happened with nearly 916 (27.89 %) victims were befallen. Men (19.77%) contributed to a greater

number of incidents as compared to the women (6.66%). When the beach was closed with red and yellow flags, there were a total of 646 (19.67 %) incidents happened with 939 (19.06 %) victims. When the beach was closed for swimming, around 43 incidents (1.31 %) were found with 128 victims (2.60 %) (Figure 7).

Conclusion

A detailed study on Surf Zone Injuries has been carried out using lifeguard data from nearly 44 Goa beaches in India for the period of 2008-2020 to examine different kinds of injuries and its relationship with the beachgoer's activities, gender, place, etc. Goa being the India's top most tourism capital and its popular beaches, we found there is a global significance to studying the SZIs. Out of all the beaches, Calangute reported the highest SZI cases followed by Baga and Candolim in the north Goa and Colva being highest in the South Goa. Reasonably highest number of incidents happened from the people of Karnataka followed by Goa. We found that rip currents are one of the primary causes of SZIs on Goa beaches contributing to nearly 59.32% of total cases with nearly 3030 victims followed by injuries due to shore breaking. Based on the analysis we determined that victims of age between 19 and 25 were suffered SZIs most and male victims are dominant in all injury types. This analysis helps the beach managers to focus on specific beaches and administer restrictions in the beaches with minimum effort. However, we have found at sometimes due to partial records of the lifeguard data, some important surf zone events were missed in the analysis. This can be fulfilled by utilizing real-time recording of events through mobiles or smartphones by way of customized applications, which will be attempted in the future.

Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Surisetty V V Arun Kumar and Ch Venkateswarlu. The data was provided by Ankit Somani. The draft of the manuscript was written by Ch Venkateswarlu and B Gireesh and all the authors were contributed in enhancing the quality of the manuscript from previous versions. C V Naidu have given overall guidance to conduct this work. All authors read and approved the final manuscript.

Ethics declarations

Conflict of Interest

The authors declare that they have no conflicts of interest; that no one had any influence over the design, execution and analysis of the study; and do not stand to gain financially or otherwsie from the recommendations and methods promoted in the paper.

Ethical approval

Ethical approval for the research was granted by the Dristi Marine Ltd. at Goa (where one the authors is the Managing Director of the company and provided the data for research purpose)

Consent for publication

All participants gave their oral consent to record their personal data in the lifeguard logs and for the outcomes to be reported publicly.

References

1. Arun Kumar SVV, Prasad KVSR (2014) Rip current-related fatalities in India: A new predictive risk scale for forecasting rip currents. Nat Hazards 70:313–335. https://doi.org/10.1007/s11069-013-0812-x
2. Brewster BC, Gould RE, Brander RW (2019) Estimations of rip current rescues and drowning in the United States. 389–397

3. Brighton B, Sherker S, Brander R, et al (2013) Rip current related drowning deaths and rescues in Australia 2004-2011. Nat Hazards Earth Syst Sci 13:1069–1075. https://doi.org/10.5194/nhess-13-1069-2013
4. Castelle B, Brander R, Tellier E, et al (2018) Surf zone hazards and injuries on beaches in SW France. Nat Hazards 93:1317–1335. https://doi.org/10.1007/s11069-018-3354-4
5. Castelle B, Scott T, Brander R, et al (2020) Wave and Tide Controls on Rip Current Activity and Drowning Incidents in Southwest France. J Coast Res 95:769–774. https://doi.org/10.2112/SI95-150.1
6. Castelle B, Scott T, Brander RW, Mccarroll RJ (2016) PT. Earth Sci Rev. https://doi.org/10.1016/j.earscirev.2016.09.008
7. Chandramohan P, Kumar VS, Jena BK (1997) Rip Current Zones Along Beaches in Goa. J Waterw Port, Coastal, Ocean Eng 123:322–328
8. da FKlein A (2003) Analysis of Hazards Associated with Sea Bathing: Results of Five Years Work in Oceanic Beaches of Santa Catarina State, Southern Brazil. J Coast Res 107–116. https://doi.org/10.2307/40928754
9. Dalrymple RA, MacMahan JH, Reniers AJHM, Nelko V (2011) Rip currents. Annu Rev Fluid Mech 43:551–581. https://doi.org/10.1146/annurev-fluid-122109-160733
10. de Korte E, Castelle B, Tellier E (2021) A Bayesian network approach to modelling rip current drownings and shore-break wave injuries. Nat Hazards Earth Syst Sci Discuss 1–26. https://doi.org/10.5194/nhess-2021-36
11. Ferrari M, Carpi L, Pepe G, et al (2019) A geomorphological and hydrodynamic approach for beach safety and sea bathing risk estimation. Elsevier B.V
12. Gilchrist J, Branche C (2018) Lifeguard effectiveness. In: The science of beach lifeguarding. CRC Press, pp 29–35
13. Jiménez JA, Osorio A, Marino-Tapia I, et al (2007) Beach recreation planning using video-derived coastal state indicators. Coast Eng 54:507–521. https://doi.org/10.1016/j.coastaleng.2007.01.012
14. MacMahan JH, Thornton EB, Reniers AJHM (2006) Rip current review. Coast Eng 53:191–208. https://doi.org/10.1016/j.coastaleng.2005.10.009
15. McCool JP, Moran K, Ameratunga S, Robinson E (2008) New Zealand beachgoers' swimming behaviours, swimming abilities, and perception of drowning risk. Int J Aquat Res Educ 2:. https://doi.org/10.25035/ijare.02.01.02
16. Ménard AD, Houser C, Brander RW, et al (2018) The psychology of beach users: importance of confirmation bias, action, and intention to improving rip current safety. Nat Hazards 94:953–973. https://doi.org/10.1007/s11069-018-3424-7
17. Muller MW (2018) Beach replenishment and surf-zone injuries along the coast of Delmarva, USA. Ocean Coast Manag 151:127–133. https://doi.org/10.1016/j.ocecoaman.2017.10.013
18. Niels West (2005) Beach use and behaviors. In: Schwartz ML (ed) Encyclopedia of coastal science. Ency_clopedia of earth science series. Springer, Dordre. Springer, PO Box 17, 3300 AA Dordrecht, The Netherlands
19. Pitman SJ, Thompson K, Hart DE, et al (2021) Beachgoers' ability to identify rip currents at a beach in situ. Nat Hazards Earth Syst Sci 21:115–128. https://doi.org/10.5194/nhess-21-115-2021
20. Puleo JA, Hutschenreuter K, Cowan P, et al (2016) Delaware surf zone injuries and associated environmental conditions. Nat Hazards 81:845–867. https://doi.org/10.1007/s11069-015-2108-9
21. Robles LA (2006) Cervical spine injuries in ocean bathers: Wave-related accidents. Neurosurgery 58:920–923. https://doi.org/10.1227/01.NEU.0000209941.18102.35
22. Short A, Brander R (2014) Beach Hazard and Risk Assessment beach hazard beach risk. Drowning 287–292. https://doi.org/10.1007/978-3-642-04253-9_41
23. Short A, Weir A (2018) Beach types, hazards and risk assessment. In: The science of beach lifeguarding. CRC Press, pp 53–65
24. (2005) Copyright ASCE 2005 Coastal Disasters 2005 SOLUTIONS TO COASTAL DISASTERS 2005 Copyright ASCE 2005 Coastal Disasters 2005. Disasters 264–274

Tables

Table 1: Year-wise demographic injury data from all the beaches of north Goa between 2008 and 2020 (n =3147). Beaches with the highest percentage of injuries are underlined.

Beach name	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total	% Victims
Anjuna	0	0	14	15	26	15	32	13	18	27	14	12	5	191	6.07
Arambol	0	0	11	16	43	14	37	31	17	29	25	100	5	328	10.43
Ashwem	0	0	1	9	6	11	10	12	11	14	26	67	6	173	5.50
Baga	14	55	45	65	89	43	75	52	61	45	19	152	21	736	23.40
Bambolim	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0.06
Calangute	10	48	71	44	91	93	79	61	89	61	42	79	7	775	24.64
Candolim	0	9	41	52	70	35	21	23	51	32	13	26	5	378	12.02
Dona Paula	0	0	1	3	2	0	0	0	1	0	1	0	0	8	0.19
Mandrem	1	0	0	0	0	0	0	0	0	0	0	7	1	9	0.29
Miramar	0	0	5	2	1	0	33	17	1	3	3	6	1	72	2.29
Morjim	0	0	4	12	10	5	17	6	16	17	40	38	0	165	5.25
Querim	0	0	0	2	4	6	1	0	2	2	3	2	0	22	0.70
Sinquerim	0	4	14	20	17	20	23	7	9	6	19	11	4	154	4.90
Siridao	0	0	3	2	0	1	0	0	1	1	0	0	0	8	0.25
Vagator	0	0	14	3	23	7	21	10	13	8	13	12	1	125	3.97
Vainguinim	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.03
Total	**25**	**116**	**225**	**244**	**381**	**251**	**349**	**232**	**290**	**246**	**218**	**512**	**56**	**3147**	100.00
Percentages															

Table 2: Year-wise Demographic injury data with all the beaches of south Goa between 2008 and 2020, n =1690. Beaches with the highest percentage of injuries are underlined.

Beach name	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total	% of victims
Agonda	0	0	2	6	15	13	6	10	24	11	8	13	2	110	6.51
Arrosim	1	3	0	0	7	8	7	9	5	7	1	9	0	57	3.37
Baina	2	4	5	8	13	0	5	6	1	8	23	2	5	82	4.85
Benaulim	7	1	9	25	32	35	11	5	4	7	19	15	9	179	10.59
Betalbatim	0	4	4	4	0	4	4	1	4	10	6	6	0	47	2.78
Betul	0	0	0	0	1	2	3	0	0	0	0	1	0	7	0.41
Bogmalo	0	3	2	1	4	2	2	4	4	4	3	1	1	31	1.83
Cabo de Ram	1	0	3	2	0	1	0	0	2	3	0	8	0	20	1.18
Canaguinim	0	0	1	1	0	0	0	0	1	0	0	0	0	3	0.18
Cavellossim	0	2	9	1	1	2	1	4	1	2	34	12	6	75	4.44
Cola	0	0	0	1	0	3	12	1	0	1	0	0	0	18	1.07
Colva	12	7	18	27	30	82	26	16	26	27	31	23	2	327	19.35
Galgibag	0	0	1	0	3	9	1	9	8	2	8	6	7	54	3.20
Hollant	0	0	2	0	0	2	0	3	0	0	1	0	0	8	0.47
Majorda	3	1	6	4	11	7	5	9	11	17	16	5	0	95	5.62
Mobor	0	0	8	7	0	23	5	11	0	5	5	9	0	73	4.32
Palolem	0	0	8	20	29	28	15	27	31	22	24	37	10	251	14.85
Patnem	0	0	2	2	3	2	1	1	0	6	6	2	0	25	1.48
Taj	0	0	0	1	0	0	1	3	3	1	0	0	0	9	0.53
Rajbagh	0	0	0	2	1	0	0	1	2	4	2	2	3	17	1.01
Uttorda	5	0	0	0	0	0	0	0	0	0	0	0	0	5	0.30
Varca	0	0	6	6	32	5	15	4	5	5	4	7	0	89	5.27
Velsao	0	1	3	2	4	2	7	3	2	3	1	3	2	33	1.95
Zalor	0	0	0	3	5	3	13	7	16	5	12	10	1	75	4.44
Total	**31**	**26**	**89**	**123**	**191**	**233**	**140**	**134**	**150**	**150**	**204**	**171**	**48**	**1690**	100.00
Percentages															

Table 3: Activity wise distribution of surf zone injuries related to gender, location (swim or non-swim zone) and causes

Activity/Cause	Male	Female	Swim zone	Non-swim zone
Surfing	583	117	45	122
Wading	621	345	61	132
Bodyboarding	380	102	59	69
Water sports	280	35	82	51
Wave attack	246	95	226	386
Health issue	409	98	127	159
Rip currents	2396	634	702	1020

Figures

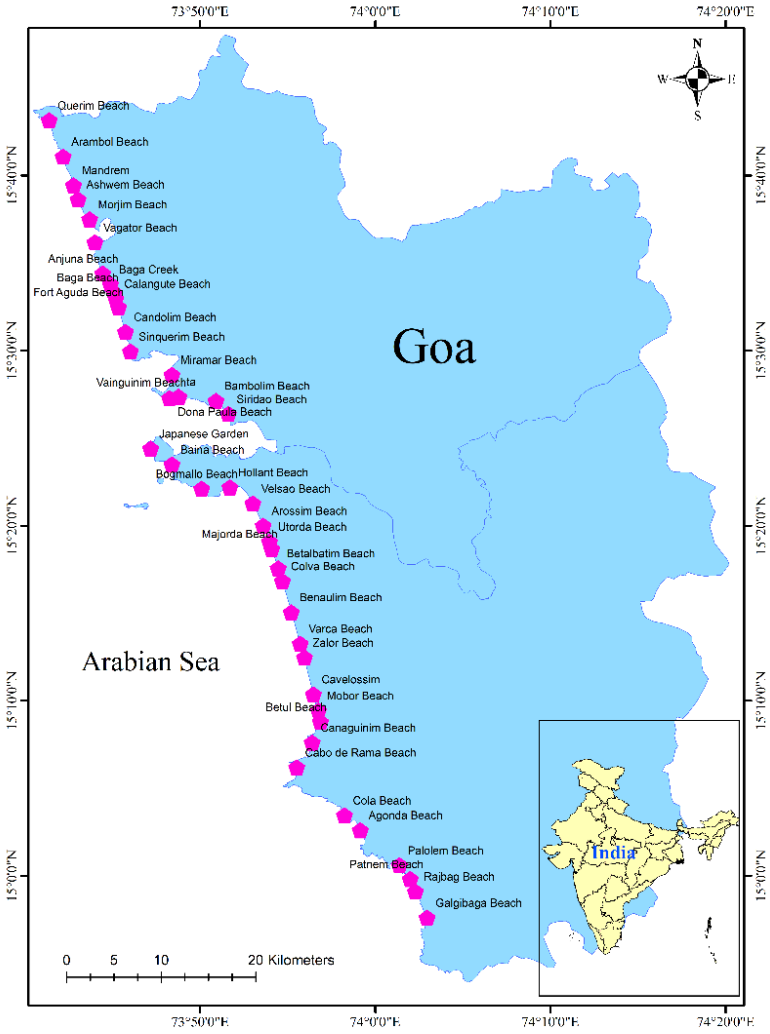
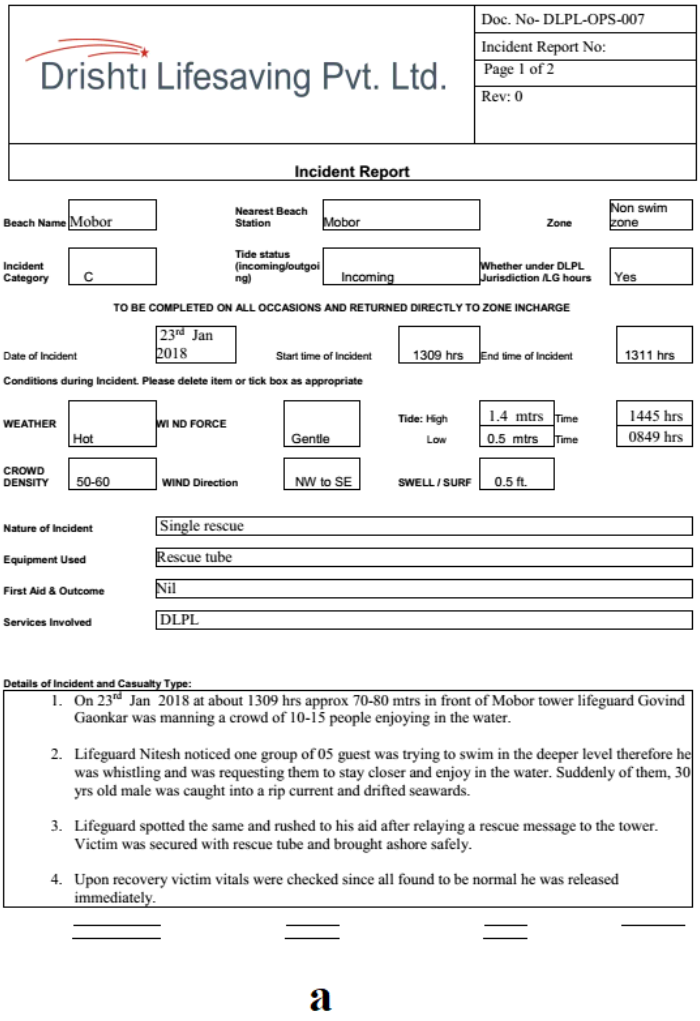


Figure 1

Study area locating Surf Zone Injuries (SZIs) incidents in Goa based on data collected from Drishti Lifesaving Ltd during 2008–2020. The filled circles indicate major beaches which receive huge visitors throughout the year.



Drishti Lifesaving Pvt. Ltd.

Doc. No- DLPL-OPS-007
Incident Report No:
Page 1 of 2
Rev: 0

Incident Report

Beach Name: Mobor | Nearest Beach Station: Mobor | Zone: Non swim zone

Incident Category: C | Tide status (incoming/outgoing): Incoming | Whether under DLPL Jurisdiction /LG hours: Yes

TO BE COMPLETED ON ALL OCCASIONS AND RETURNED DIRECTLY TO ZONE INCHARGE

Date of Incident: 23rd Jan 2018 | Start time of Incident: 1309 hrs | End time of Incident: 1311 hrs

Conditions during Incident. Please delete item or tick box as appropriate

WEATHER: Hot | WIND FORCE: Gentle | Tide: High 1.4 mtrs Time 1445 hrs | Low 0.5 mtrs Time 0849 hrs

CROWD DENSITY: 50-60 | WIND Direction: NW to SE | SWELL / SURF: 0.5 ft.

Nature of Incident: Single rescue

Equipment Used: Rescue tube

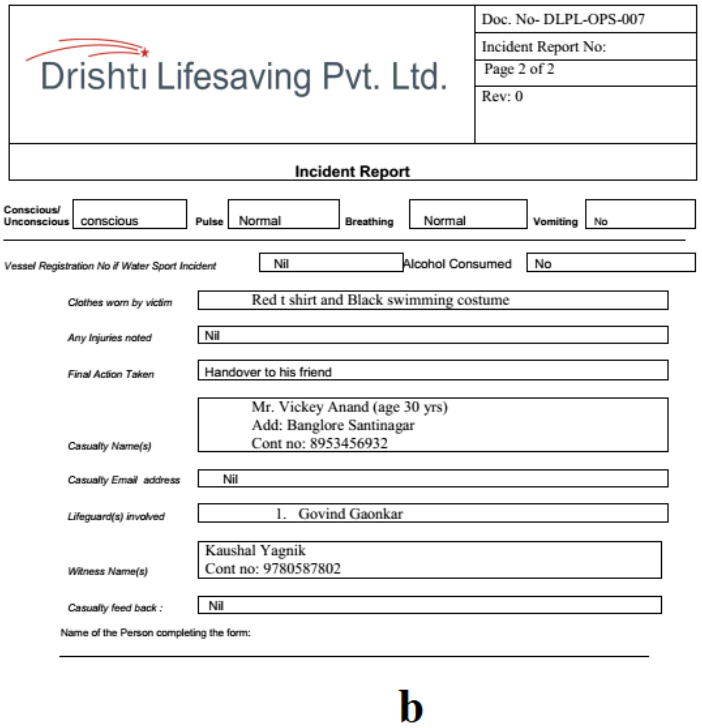
First Aid & Outcome: Nil

Services Involved: DLPL

Details of Incident and Casualty Type:

1. On 23rd Jan 2018 at about 1309 hrs approx 70-80 mtrs in front of Mobor tower lifeguard Govind Gaonkar was manning a crowd of 10-15 people enjoying in the water.
2. Lifeguard Nitesh noticed one group of 05 guest was trying to swim in the deeper level therefore he was whistling and was requesting them to stay closer and enjoy in the water. Suddenly of them, 30 yrs old male was caught into a rip current and drifted seawards.
3. Lifeguard spotted the same and rushed to his aid after relaying a rescue message to the tower. Victim was secured with rescue tube and brought ashore safely.
4. Upon recovery victim vitals were checked since all found to be normal he was released immediately.

a



Drishti Lifesaving Pvt. Ltd.

Doc. No- DLPL-OPS-007
Incident Report No:
Page 2 of 2
Rev: 0

Incident Report

Conscious/ Unconscious: conscious | Pulse: Normal | Breathing: Normal | Vomiting: No

Vessel Registration No if Water Sport Incident: Nil | Alcohol Consumed: No

Clothes worn by victim: Red t shirt and Black swimming costume

Any Injuries noted: Nil

Final Action Taken: Handover to his friend

Casualty Name(s): Mr. Vickey Anand (age 30 yrs)
Add: Banglore Santinagar
Cont no: 8953456932

Casualty Email address: Nil

Lifeguard(s) involved: 1. Govind Gaonkar

Witness Name(s): Kaushal Yagnik
Cont no: 9780587802

Casualty feed back : Nil

Name of the Person completing the form:

b

Figure 2

(Part-A) Sample lifeguard log of an incident/injury reported used by DLSL at Mobor beach on 23rd January 2018

(Part-B) Sample lifeguard log of an incident reported at Mobor beach on 23rd January 2018

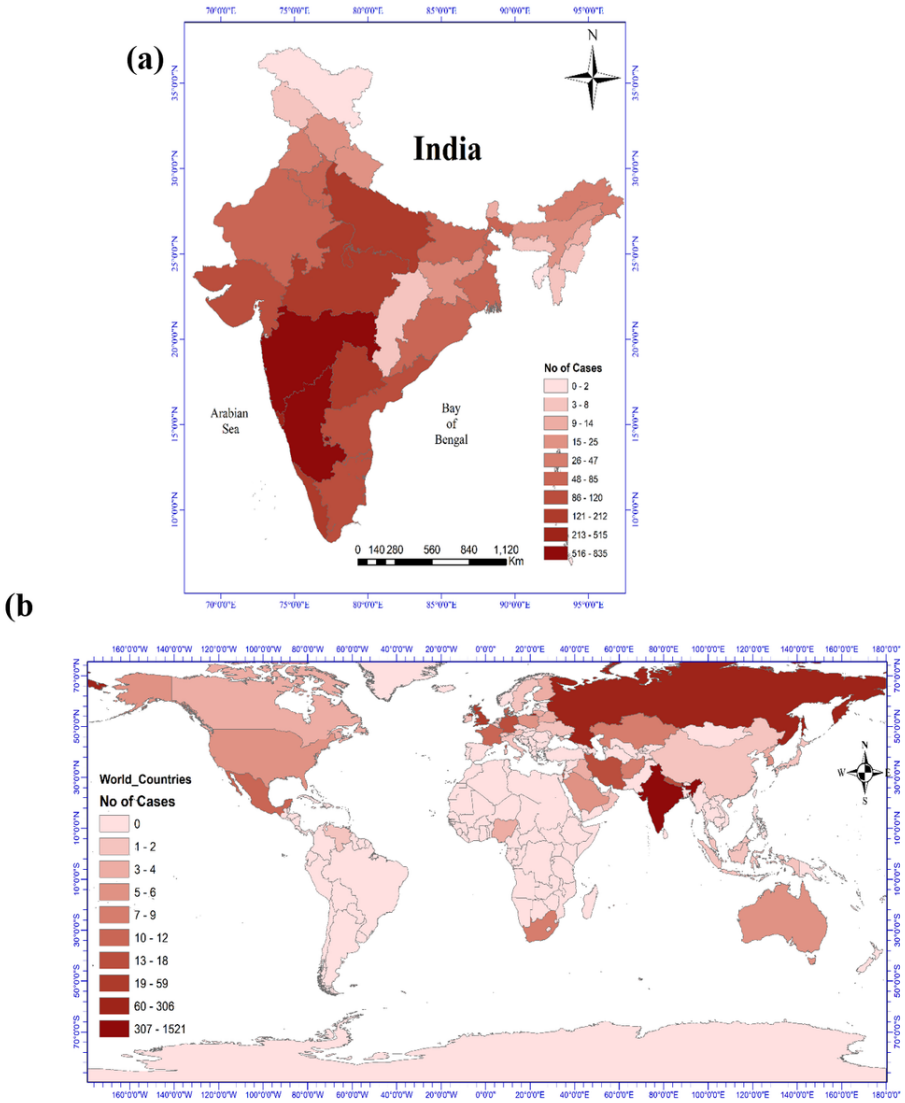


Figure 3

Geographical distribution of Surf Zone Injuries recorded in the study area and its distribution with the victim's address in (a) Indian state and (b) country

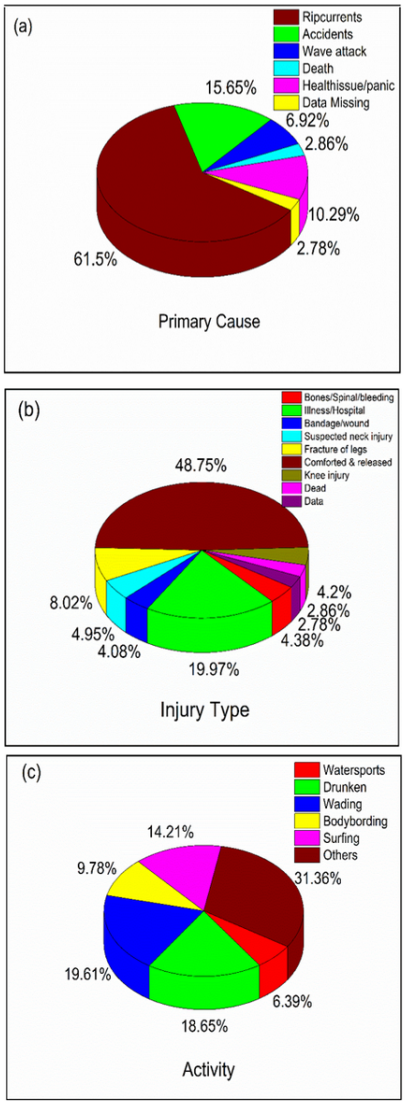


Figure 4

Distribution of Surf Zone Incidents related to (a) Primary cause (b) Incident type and (c) Activity of the victims

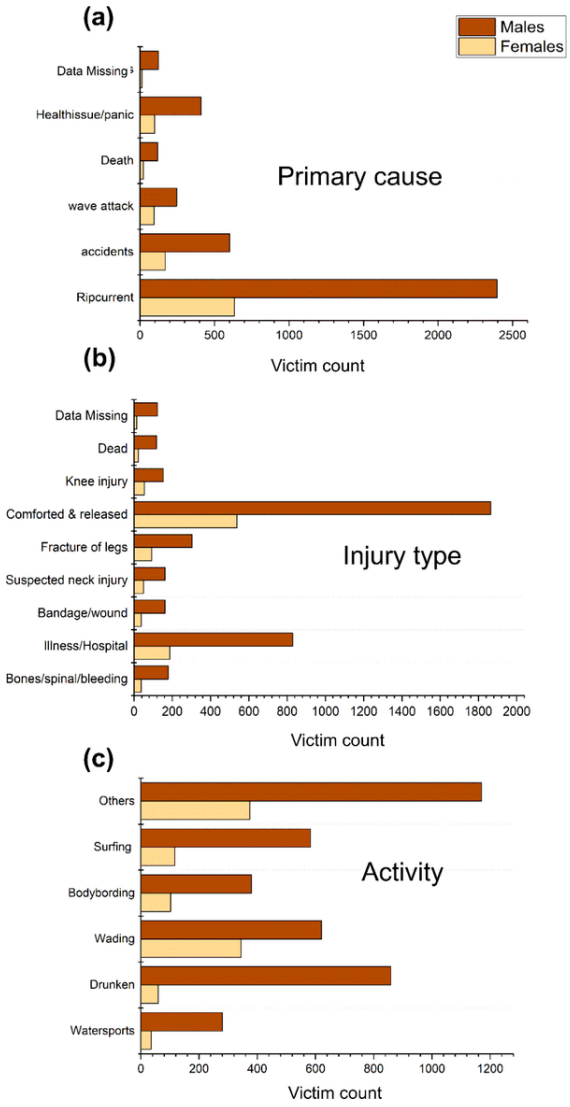


Figure 5

Gender distribution of surf zone victim count related to (a) Primary cause (b) Incident type and (c) Activity of the victims

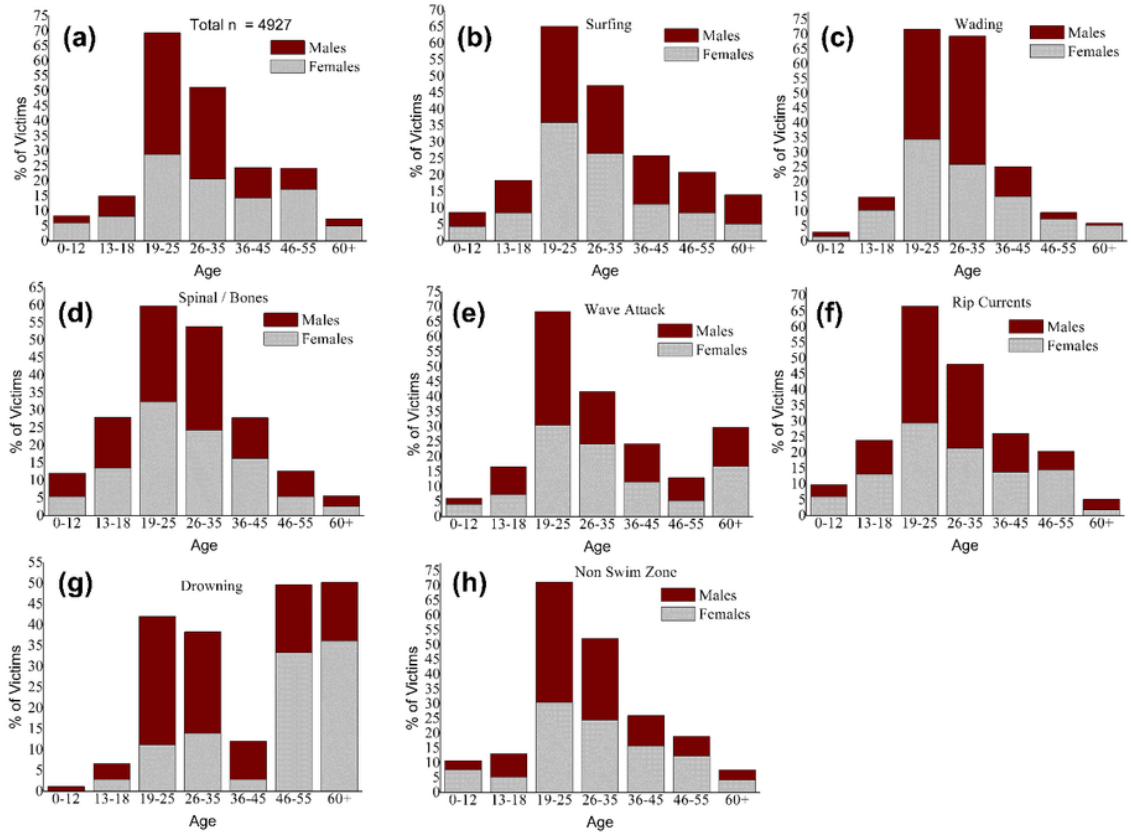


Figure 6

Age and gender distribution of SZIs for (a) total incidents within the swim zone; (b) surfing; (c) wading; (d) spinal or bone injuries; (e) injuries due to wave attack; (f) injuries due to rip currents; (g) drowning deaths and (h) injuries in non-swim zone

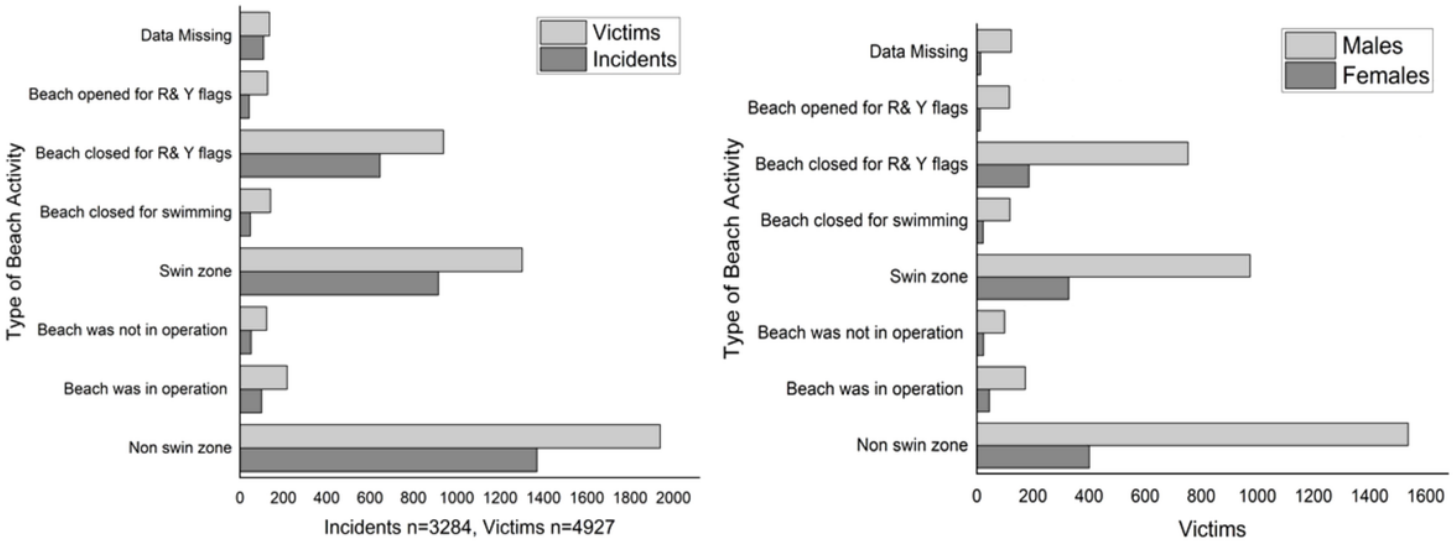


Figure 7

Surf Zone Injuries categorized by (a) Type of beach activity (c) Primary cause (e) Type of Injury by activty and (b,d and f) are male and female victims of each category.