

# Drowning Mortality and Risk Factors in Coastal Iran: A Cross-Sectional Study Using GIS

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Received 2025-01-08; Accepted 2025-08-25; Online Published 2025-12-29

## Abstract

**Introduction:** Drowning is a leading cause of unintentional injury-related deaths worldwide, with significant geographical variations in mortality rates. This study aims to identify high-risk drowning areas and assess epidemiological trends using Geographic Information Systems (GIS) from 2016 to 2022.

**Method:** A cross-sectional analytical study was conducted using data recorded by the Emergency and Medical Incident Management Center of Gilan Province. A total of 588 drowning incidents were analyzed, considering variables such as age, gender, seasonality, and geographical location. GIS software was used to map high-risk areas using Spot and Heatmap techniques, while statistical analyses were conducted in Stata. The Odds Ratio (OR) index was used to assess risk levels.

**Result:** Of the 588 reported drowning incidents, 497 were non-fatal, while 91 resulted in fatalities. The majority of incidents (474 cases) occurred in high-risk locations. Male individuals accounted for 77.21% of the total cases and 81.98% of fatalities, highlighting gender disparities in drowning rates. Rasht County recorded the highest number of fatalities (20 deaths), while Shaft and Sowme'eh Sara had zero reported drowning deaths. Geographic analysis using GIS mapping revealed that most drowning incidents occurred along the shorelines and river confluences, particularly in Bandar Anzali, Rasht, Astarabad, and Rudsar. Odds Ratio (OR) indicated that men had significantly higher drowning risks than women (OR = 2.57, 95% CI: 2.21–2.96), and drowning risk was notably elevated in coastal zones (OR = 3.19, 95% CI: 2.65–3.85)

**Conclusion :** Drowning mortality in Gilan Province is disproportionately higher among older men, primarily due to occupational exposure, risky behaviors, and environmental factors. Preventive measures such as enhanced safety regulations, swimming education programs, improved tourist signage, and stricter enforcement of occupational safety standards are recommended to reduce drowning incidents. Identifying high-risk zones through GIS analysis provides valuable insights for targeted interventions and policy development.

**Keywords:** Drowning epidemiology, Geographic Information System (GIS), Public health, Risk assessment, Preventive strategies

## Introduction

Drowning is one of the most common yet preventable accidents in the world. According to the World Health Organization's report in 2015, drowning is the third leading cause of unintentional injury deaths, claiming the lives of 372,000 people annually and accounting for 7% of all injury-related deaths<sup>1, 2</sup>. According to the

World Health Organization (WHO) report, in 2019 alone, 236,000 people lost their lives due to drowning. In that same year, drowning was the third leading cause of unintentional injuries globally, accounting for 8% of all deaths and 7% of all injury-related deaths<sup>3</sup>. According to statistics published by the Ministry of

Health, Treatment, and Medical Education of Iran, there are significant geographical differences in the drowning patterns in this country. The drowning mortality rate varies from 4.1 per 100,000 populations in a coastal area in northern Iran to less than 0.9 per 100,000 populations in central Iran, where there is no access to the sea <sup>1</sup>.

Iran, due to its proximity to natural waters such as the Caspian Sea and the Persian Gulf, and to various internal water resources such as rivers, lakes, dams, pools, qanats, and seas, is one of the countries at high risk of drowning. According to the Global Burden of Disease (GBD) report in 2017, the number of drowning deaths in Iran in 2017 was 104,373. Drowning is the tenth leading cause of death among men and the twenty-fifth among women in terms of the number of deaths from all causes. Despite preventive measures, including the establishment of drowning prevention campaigns that mainly focus on raising awareness among at-risk local communities, drowning still accounts for a significant number of deaths in Iran. The high drowning mortality rate in Iran indicates the necessity for further studies in this field <sup>2</sup>. Coastal areas of the country, including Gilan Province, which borders the Caspian Sea and is recognized as one of the important areas at risk of drowning, require comprehensive epidemiological studies to understand the dynamics and risk factors associated with drowning incidents. The beaches of Gilan Province, along the Caspian Sea, highlight the need for targeted interventions and informed public health strategies to reduce this preventable cause of mortality <sup>4</sup>. In coastal areas like Gilan Province, Iran, factors such as wave dynamics, swimming skills, and environmental conditions interact to influence drowning risks, necessitating explicit spatial analyses <sup>5</sup>.

Geographic Information Systems (GIS) are crucial for predicting and providing a comprehensive population distribution model for a specific area and for identifying at-risk populations, thanks to their provision of evidence-based spatial information. Understanding the nature of the environment where drowning occurs has a significant impact on providing drowning prevention strategies. Although the various applications of Geographic Information Systems (GIS) and their benefits for health and hygiene, particularly in epidemiological studies, are well known, few studies have examined drowning using these systems <sup>6</sup>. Geographic Information Systems (GIS) have emerged as transformative tools in public health epidemiology. They enable the integration of multi-layered spatial data to model risk patterns and optimize intervention strategies <sup>7, 8</sup>. Efforts to reduce drowning rates should include multifaceted approaches, such as education,

community engagement, and collaboration with local stakeholders to foster a safety culture and awareness regarding water-related activities <sup>9, 10</sup>.

Integrating these strategies with robust epidemiological research and GIS mapping enables the establishment of sustainable and effective drowning prevention initiatives in Gilan Province. This research aims to determine the epidemiological status and identify accident-prone areas in Gilan province concerning drowning using a Geographic Information System (GIS) to provide a comprehensive picture of the dynamics of drowning in the region. This method helps identify high-risk locations but also aids in developing preventive measures tailored to the area's unique characteristics.

## Methods

This study employs a cross-sectional analytical design to examine drowning incidents across Gilan Province, Iran, spanning 2016 to 2022. Data were collected from the Emergency and Medical Incident Management Center, which systematically records drowning events. The primary objective was to leverage Geographic Information Systems (GIS) to identify high-risk drowning zones and to assess epidemiological trends to inform evidence-based intervention strategies.

In northern Iran, Gilan Province covers 14,700 square kilometers, extending along the Caspian Sea and bordering Mazandaran, Ardabil, Zanjan, and Qazvin provinces. With an extensive 288-kilometer coastline, the region features diverse water bodies, including rivers, lakes, dams, pools, and qanats, contributing to heightened drowning risks. The province experiences a humid subtropical climate, with rainfall peaking between September and December, averaging 1,400-1,900 mm annually.

The dataset incorporated multiple variables to facilitate a comprehensive analysis. Temporal factors included the month, season, and time of occurrence, categorized as morning, afternoon, or night. Demographic characteristics encompassed age and gender, while incident outcomes differentiated between fatal and non-fatal cases. Geographic and environmental data were used to classify incident locations, distinguishing between designated safe zones and high-risk areas. Additionally, the spatial distribution of drowning events was mapped across the 12 counties of Gilan Province. Geospatial analyses were conducted using GIS software, integrating Spot and Heatmap techniques to visualize drowning patterns. Spot maps pinpointed individual incident locations, while Heat maps quantified risk intensities across counties, identifying clusters of drowning cases along rivers and the Caspian Sea coastline. These tools enabled spatial differentiation

in drowning prevalence based on environmental and geographic variables.

**Ethics approval**

The study received approval from the Ethics Committee of the School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran. (ethics code: IR.SBMU.PHNS.REC.1403.159).

**Statistical analysis**

Statistical modeling was performed in Stata to ensure a rigorous quantitative assessment. Incident frequencies and regional distributions were calculated, while relative drowning risks were determined using Odds Ratio (OR) analysis. The OR index quantified the effects of gender, geographic exposure, and county-level vulnerability, enabling an in-depth epidemiological evaluation. A 5% significance threshold was applied across all statistical tests to maintain the reliability of results.

**Results**

Table1, Summarizes the distribution of drowning incidents based on different variables, including location, outcome, and year.

Variables		Male (N, %)	Female (N, %)	Total (N, %)
Place	safe	64 (75.29)	21 (24.71)	85 (100)
	Dangerous	369 (77.85)	105 (22.15)	474 (100)
Outcome	Alive	363 (76.10)	114 (23.90)	477 (100)
	Dead	91 (81.98)	20 (18.02)	111 (100)
Year of Study	2016	58 (75.32)	19 (24.68)	77 (100)
	2017	63 (75.90)	20 (24.10)	83 (100)
	2018	57 (82.61)	12 (17.39)	69 (100)
	2019	72 (90.00)	8 (10.00)	80 (100)
	2020	45 (81.82)	10 (18.18)	55 (100)
	2021	49 (75.38)	16 (24.62)	65 (100)
	2022	110 (69.18)	49 (30.82)	159 (100)
	Total	454 (77.21)	134 (22.79)	588 (100)

Table 2 shows the odds ratios for factors influencing the outcome of drowning incidents. The odds ratio for gender is OR=0.699 (CI 95%; 0.412, 1.186), which indicates that the likelihood of drowning-related deaths in women is lower than in men, although the difference is not statistically significant (P=0.185). The odds ratio for location is OR=7.624 (CI 95%; 2.361, 24.616), which indicates that the likelihood of drowning deaths in hazardous locations is significantly higher than in safe locations. (P=0.001) The odds ratio for age is OR=1.006 (CI 95%; 0.995, 1.017), indicating a negligible effect of age on the likelihood of drowning death, where the risk of death increases with age, but this result is not statistically significant (P=0.217). Table 3 summarizes drowning incidents and their outcomes in various counties of Gilan province. Three counties

Based on the findings, a total of 588 drowning incidents were reported and recorded in Gilan province between 2016 and 2022, of which 497 were non-fatal, and 91 were fatal. Most drowning incidents occurred in high-risk locations, totaling 474 incidents, compared to 85 incidents in safe locations. Men were more likely to experience drowning incidents than women, with 77.85% of incidents in high-risk locations and 75.29% in safe locations involving men. According to the results, 477 people were rescued from drowning incidents, of which 76.10% were men and 23.90% were women. Unfortunately, 111 people lost their lives, with a higher percentage of men (81.98%) compared to women (18.02%) losing their lives. Over the years, the number of drowning incidents varied, with the highest number occurring in 2022, totaling 159 incidents. Overall, from 2016 to 2022, 588 drowning incidents occurred, with men constituting 77.21% and women 22.79% of the cases.

reported the highest number of cases: Rasht County reported 111 incidents, with 91 non-fatal and 20 fatal cases; Bandar Anzali County reported 97 incidents, with 85 non-fatal and 12 fatal cases; and Astan-e Ashrafiyeh County recorded 94 drowning incidents, with 82 non-fatal and 12 fatal cases. Shaft and Sowme'eh Sara had the fewest non-fatal cases, with 2 and 5, respectively. The results of the incident location analysis are shown in Figures 1-3. Based on the results in Figure 1, most drowning cases occurred along the shore and at the confluence of rivers with the Caspian Sea. Bandar Anzali, Rasht, Astarabad, and Rudsar shores had the highest number of incidents during the study period (Figure 1). Additionally, based on the results shown in Figure 2, Rudsar County had the highest number of non-fatal drowning incidents, with 102 cases. The counties

of Bandar Anzali, Rasht, and Astanah-ye Ashrafiyeh also reported higher rates of non-fatal drowning incidents compared to other counties during the study period (Figure 2). Rasht recorded the highest number of drowning deaths, with 20 fatalities. This indicates a critical area where drowning incidents often result in

fatalities. Overall, both Shaft and Soume'eh Sara counties had the lowest number of drowning deaths, each with 0 cases. This shows that these counties did not report any drowning fatalities during the study period (Figure 3).

Table2, the odds ratios for different factors affecting the outcome of drowning incidents

Outcome	Odds ratio	Std. err.	z	P>z	[95% conf. interval]
Sex (Female)	0.699	0.188	-1.33	0.185	0.412 1.186
Place (Dangerous)	7.624	4.559	3.4	0.001	2.361 24.616
Age	1.006	0.005	1.23	0.217	0.995 1.017

Table3, summarizes the number of drowning incidents and the outcomes in different townships within Gilan Province.

Township	Drowning Total	drowning non-fatal	drowning fatal cases
Astaneh-ye-Ashrafiyeh	94	82	12
Astara	26	23	3
Bandar-e Anzali	97	85	12
Fuman	8	7	1
Hashtpar	44	38	6
Lahijan	14	9	5
Langrud	56	43	13
Rasht	111	91	20
Rudbar	16	11	5
Rudsar	116	102	14
Shaft	2	2	0
Sume'eh Sara	5	5	0
Gilan Province	588	497	91

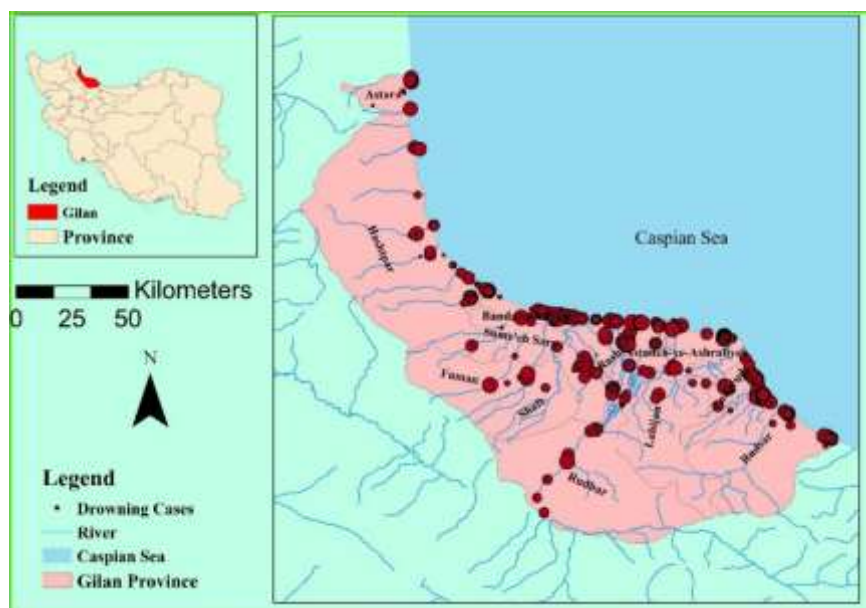


Figure1, Distribution of Drowning Cases in Gilan Province



Figure2, Distribution of Drowning (non-fatal incidents) in Gilan Province based on township region

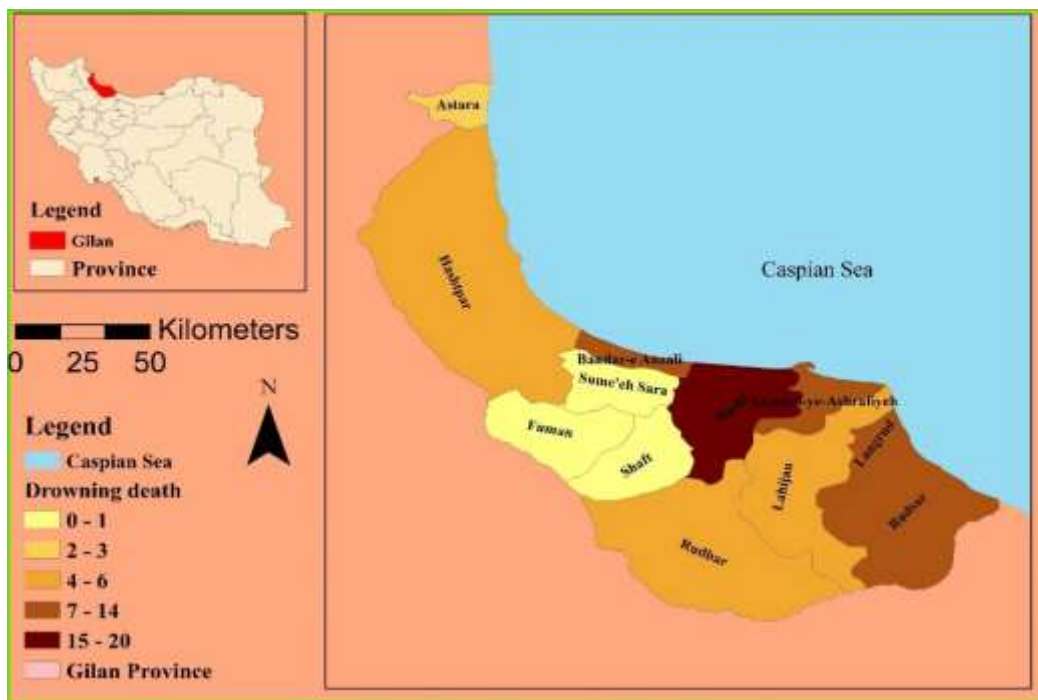


Figure3, Distribution of Drowning (fatal incidents) in Gilan Province based on township region

**Discussion**

The results of the present study showed that between the years 2016 and 2022, 588 drowning incidents occurred in Gilan province, resulting in the deaths of 91 individuals, with most drowning incidents (474 cases) happening in high-risk areas.

The results of this study showed that the rate of drowning and mortality among men was higher than that among women. The results of a study conducted in 2023, which examined the application of the Haddon matrix in identifying drowning prevention strategies in northern Iran, indicated that the likelihood of drowning

and mortality in men is more than twice that in women. The reason for this is that, compared to women, men engage in riskier behaviors such as swimming alone or after consuming alcohol, making them more susceptible to drowning<sup>3</sup>.

The results of a study conducted in Canada, which examined drowning mortality rates from 2008 to 2012, reported a mortality rate in men compared to women of 5 to 1<sup>11</sup>. The results of a review study conducted in 2017, which examined the epidemiology of drowning in low- and middle-income countries, showed that the drowning mortality rate in men was 75% and in women 25%<sup>12</sup>. A comparative review indicates that the results of the studies conducted are consistent with the present studies and emphasize that the mortality and drowning rates in men are higher than in women. One of the possible reasons for the higher drowning rate among men compared to women is their occupations, as men may work in jobs such as boating in tourist areas to transport tourists and fishing, which are more prone to drowning and mortality. On the other hand, studies have shown that drug and alcohol use among men has led them to engage in risky behaviors such as not wearing life jackets and not paying attention to drowning warnings.

In this study, it was shown that the drowning rate in 2022 increased compared to previous years. The results of a study that examined a global study on drowning mortality until 2017 indicated that the rate of unintentional drowning deaths decreased between 1990 and 2017<sup>13</sup>. The results of a study by colleagues in 2019 in Iran, which examined the trend of drowning mortality from 1990 to 2015, showed that the drowning mortality rate in Iran decreased from 1990 to 2015<sup>14</sup>. The results of a study in Iran, which examined statistical models to predict drowning in 2019, indicated that the number of drownings in Iran is decreasing and will decrease at a steeper rate in the future<sup>15</sup>. Comparing the results of the conducted studies with those of the present study shows they are not aligned, and several reasons may explain this discrepancy.

One of these factors is the year the study was conducted; the present study reported a high mortality rate in 2022, which could be partly due to increased migration to northern regions of the country and residence in unauthorized and dangerous places, as well as the increase in the number of tourists and their unfamiliarity with swimming and the dangerous areas of the region.

Therefore, preventive measures such as educating tourists, improving beaches, and expanding protected areas on the country's beaches can be beneficial in this regard.

The results of this study indicate that the rate of drowning and the resulting mortality are higher among older individuals. The findings of a study in New Zealand, which examined drowning risk factors in 2017, showed that drowning rates were higher in older age groups, attributed to their occupations and alcohol consumption, as well as their lack of wearing life jackets<sup>16</sup>. The results of a study in Mazandaran province in 2018, which investigated drowning incidents from 2011 to 2014, revealed that the highest drowning rates were in the age group of 20-24 years<sup>17</sup>. A comparative analysis of the results shows that the rates of drowning and mortality increased with age. Since most older individuals in the northern regions of the country may be engaged in occupations related to the sea and coast, they are at a higher risk of drowning, necessitating adherence to occupational standards at sea and the use of non-defective boats.

The results of the present study showed that the drowning rate is higher in high-risk areas. The results of one study indicated that in India, due to its vastness and access to abundant water resources, including rivers, lakes, and extensive coastal areas, drowning is one of the most common causes of death among various types of mortality in this country<sup>18</sup>. On the other hand, studies have shown that drowning prevention interventions based on specific locations have been effective<sup>19</sup>. Therefore, governments should install barriers to control access to water around rivers and canals and develop educational programs on swimming, water safety, and safe rescue skills. Additionally, beach safety education should be prioritized. Furthermore, expert recommendations should be provided to improve the safety of tourism companies.

## Conclusion

The results of the present study showed that the rate of drowning and related fatalities among older men was higher compared to other age and gender groups. Since older men are more frequently engaged in work at the seaside due to the nature of their jobs, they are more exposed to drowning and fatalities. Therefore, adhering to preventive measures such as swimming education, providing guide signs for tourists, paying attention to

meteorological warnings regarding rough sea conditions, using life jackets, following occupational standards at sea, and using non-defective boats can somewhat reduce their drowning and fatality rates. Additionally, governments should identify high-risk areas for residents and tourists using various markers and prevent individuals who do not adhere to safety standards from entering them.

### Acknowledgments

We would like to express our gratitude to the Emergency and Medical Incident Management Center of Gilan Province for providing the data necessary for this study. We also thank the Safety Promotion and Injury Prevention Research Center, Institute for Health Sciences and Environment at Shahid Beheshti University of Medical Sciences for their support and resources throughout the research process.

### Conflict of Interest Disclosures

The authors declare no conflicts of interest related to this study. There are no financial or personal relationships that could influence the work reported in this manuscript.

### Funding Sources

This research was supported by Safety Promotion and Injury Prevention Research Center, Institute for Health Sciences and Environment at Shahid Beheshti University of Medical Sciences with ethics code: IR.SBMU.PHNS.REC.1403.159.

### Authors' Contributions

ZGH, AS: Conceptualization, methodology, and writing the original draft.

YV, AS, JM, MJ, AAZF: Data analysis and interpretation, and critical revision of the manuscript.

YV, MJ: GIS mapping and visualization, and data collection.

NJ, AS, AAZF: Literature review and drafting discussion sections.

ZGH: Supervision and project administration.

### Ethical Statement

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the

School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran (ethics code: IR.SBMU.PHNS.REC.1403.159).

### Declaration of Generative AI and AI-assisted technologies

The authors declare that no generative AI or AI-assisted technologies were used in the writing or analysis of this manuscript.

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