Fishing Vessel Safety in Indonesia: A Study of Accident Characteristics and Prevention Strategies

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ABSTRACT

Fishing is a crucial economic activity in Indonesia, supporting millions of people's livelihoods and food security. However, it is also one of the most hazardous occupations, exposing workers to various risks of accidents, injuries, and fatalities. Fishing vessel accidents can severely affect crew members, vessels, and marine ecosystems, resulting in human losses, economic damage, environmental impacts, and social problems. This study aims to analyze the types, locations, and causes of fishing vessel accidents in Indonesia, using data from various sources, such as official reports, maritime authorities, and news articles. The results show that the most common types of accidents are drowning, burning, and injury or death of ship crew. The most frequent locations of accidents are the Java Sea and the Malacca Strait. The main causes of accidents are human error, weather conditions, technical factors, and environmental factors. The study concludes that fishing vessel safety is a complex issue that requires a comprehensive and collaborative approach involving various stakeholders. The study also suggests possible solutions to improve fishing vessel safety, such as improved design and construction standards, enhanced weather forecasting and warning services, effective safety management systems, and behaviour change interventions. This study contributes to the literature on fishing vessel accidents and provides valuable insights for policymakers, stakeholders, and researchers in Indonesia.

1. INTRODUCTION

Fishing is one of Indonesia's most important economic sectors, providing livelihoods for millions of people and contributing to food security and foreign exchange earnings. According to the Ministry of Marine Affairs and Fisheries (MMAF), Indonesia has the second-largest fishery production in the world, with 7.2 million tons of capture fisheries and 16.6 million tons of aquaculture in 2019 [1]. However, fishing is also one of the most hazardous occupations in the world, exposing workers to various risks of accidents, injuries, and fatalities. Fishing boat accidents can severely affect crew members, vessels, and marine ecosystems, resulting in human losses, economic damage, environmental impacts, and social problems. Fishing boat accidents in Indonesia are a severe concern that requires urgent attention and action. In 2021, many accidents involving fishing vessels caused deaths, injuries, or property losses. For instance, in January 2021, a fishing boat capsized in the Java Sea due to bad weather, killing 10 crew members [2]. In February 2021, a fishing boat collided with a cargo ship in the Malacca Strait, leaving 17 crew members missing [3]. In March 2021, a fishing boat caught fire in the Banda Sea due to an electrical short circuit, injuring four crew members [4]. These are just some examples of the many incidents throughout the year.

Despite the high frequency and severity of fishing boat accidents in Indonesia, more comprehensive and systematic data and analysis are needed. Most existing studies on fishing boat accidents in Indonesia must be expanded in scope, methodology, or quality. For example, some studies only focus on specific regions or types of vessels [5], some studies rely on secondary data or anecdotal evidence without verification or validation [6, 7], and some studies lack theoretical frameworks or rigorous statistical methods [8]. Therefore, there is a need for a more comprehensive and reliable study on fishing boat accidents in Indonesia that can provide a clear picture of the trends, causes, and effects of these accidents and suggest effective measures to prevent or reduce them. The current state of research on fishing vessel safety in Indonesia reveals a multifaceted approach encompassing crew competency, safety practices, operational aspects, and accident prevention. Studies emphasize the necessity for enhanced safety measures due to inadequate adherence to safety practices [8]. Crew competency has been a focal point,

with specific evaluations conducted in various regions [9]. Additionally, investigations into the operational aspects of traditional small fishing boats have been undertaken, considering factors such as operability and hull design. These studies collectively underscore the critical need for improved safety protocols and practices within the Indonesian fishing fleet to mitigate the risks associated with potential accidents and enhance overall safety standards. This study aims to fill this gap by analyzing three years of fishing boat accident data in Indonesia (2018-2021) to identify patterns, causes, and potential safety measures. The data were obtained from the National Transportation Safety Committee [10], the official agency responsible for investigating maritime accidents in Indonesia [11], and other sources such as news reports or academic articles. The study uses descriptive and inferential statistics to analyze the data and test hypotheses. The study reviews relevant literature on fishing boat accidents and maritime safety from national and international sources. The study enhances maritime safety and prevents future accidents by providing empirical evidence and practical recommendations for policymakers, stakeholders, and researchers.

2. METHOD

This study used graphics to present and analyze the data on fishing boat accidents in Indonesia from 2018 to 2021. The data were collected from official reports, maritime authorities, and news articles. The data were evaluated by checking the sources' credibility, accuracy, timeliness, and relevance. The method consisted of four steps: data collection, data evaluation, data display, and data reference. Each step is described below:

- Data collection: The data collection process involved gathering accident data from various sources detailing fishing boat accidents in Indonesia between 2018 and 2021. The primary data source was the National Transportation Safety Committee (NTSC), the official agency tasked with investigating maritime accidents in Indonesia, supplemented by information from reputable media outlets. The data collection focused on incidents occurring in Indonesian waters during the specified timeframe.
- Data evaluation: The evaluation focused on scrutinizing the data sources' credibility, accuracy, timeliness, and relevance. Credibility assessment encompassed evaluating the maritime safety sources' qualifications, affiliations, expertise, and reputation to ensure the information's reliability. Accuracy evaluation involves cross-referencing data from multiple sources and verifying facts with evidence or references to ascertain the precision of the information. Timeliness and relevance were evaluated by considering factors such as publication date, update frequency, coverage scope, and alignment with the research topic to determine the suitability of the sources for the study. The data collection process involved active participation from 11 staff members of the National Transportation Safety Committee (NTSC) to guarantee the accuracy and comprehensiveness of the dataset. These individuals meticulously documented details of each ship accident incident in Indonesian waters, ensuring validation from local authorities to maintain data integrity. The information recorded included crucial details such as the

date and time of reporting, type of ship, ship's name, IMO number, ship's flag, date of the incident, type of accident, location of the accident, and a comprehensive description of the ship accident. Notably, the NTSC data contributor consistently registered their name as the data inputter for each ship accident, assuming responsibility for data accuracy and promptly addressing any necessary revisions. The dataset, comprising 1635 thoroughly verified ship incidents over three years, was subsequently published in the annual NTSC performance report, forming the cornerstone of the research study on fishing vessel safety in Indonesia. The meticulous collaboration between the NTSC and other sources, coupled with the rigorous data collection process, ensured the reliability and robustness of the dataset, thereby bolstering the credibility and validity of the study's outcomes.

- Data display: Data was displayed using a descriptive method in graphic form to effectively present and analyze trends, patterns, causes, and effects of fishing boat accidents. Various graphics, including tables, charts, maps, and diagrams, were utilized to showcase the data based on their specific characteristics and purposes. Tables were employed to illustrate the frequency and percentage of accidents by year, month, location, type, and cause; charts were utilized to demonstrate the distribution and comparison of accidents across different variables; maps were used to visualize the spatial distribution and density of accidents in various regions; and diagrams were employed to depict causal relationships and factors contributing to accidents. These graphics were generated using Microsoft Excel and Origin. In addition to the graphical representation of data, the study incorporated references from international journal sources and maritime safety regulations to establish a theoretical framework, conduct a literature review, and discuss the research findings. The selection of sources was based on criteria such as relevance, currency, quality, and authority, with online databases utilized for sourcing. The identified sources were evaluated by summarizing their key arguments, findings, methodologies, and implications. The study encompassed comprehensive data on ship accidents in Indonesian waters from 2018 to 2021, with no sampling involved, encompassing all available incidents. The dataset, comprising 16 variables including details like timestamp, month, contributor, type of ship, ship name, IMO number, accident date, accident type, investigation status, accident location, casualties, and province of the accident location, was organized and classified based on ship type, water location, month of the accident, and factors contributing to the accidents, further categorized into human, technical, environmental, and operational factors.
- Data references: Data reference involved consulting various international journal sources and sea safety regulations to establish a theoretical framework, conduct a literature review, and discuss the research findings. The selection of sources was meticulously carried out by searching online databases and considering factors such as relevance, currency, quality, and authority. The chosen sources were critically reviewed by summarizing their main arguments, findings, methodologies, and implications. This process ensured that the study was underpinned by robust and credible references,

enhancing the validity and reliability of the research outcomes. Incorporating diverse sources enriched the study's theoretical foundation and provided a comprehensive understanding of fishing vessel accidents in Indonesian waters.

3. RESULT AND DISCUSSION

Fishing boat accidents in Indonesia are a serious concern, as they threaten the lives and livelihoods of fishers and their families, as well as the marine environment and biodiversity. According to the National Transportation Safety Committee (KNKT), fishing vessels accounted for 31% of the total ship accidents during 2018-2020, making them the most vulnerable category. The KNKT reported that an average of 100 fishers died or went missing every year because of fishing boat accidents, with a total of 342 casualties during that period [12]. The number of fishing vessel accidents per year varied from 85 in 2018 to 271 in 2020, with a slight decrease to 98 in 2021, as shown in Figure 1 and Figure 2. Figure 3 illustrates trends in the incidence rates of accidents involving fishing vessels. Over the 46 months from 2018 to 2021, the data reveals an average of 36 incidents per year, which amounts to approximately 3 incidents per day with increasing indications. These statistics highlight the pressing need to improve the safety standards and practices of fishing vessels in Indonesia, as well as to strengthen monitoring and enforcement mechanisms to combat illegal, unreported and unregulated (IUU) fishing [13] and [14].
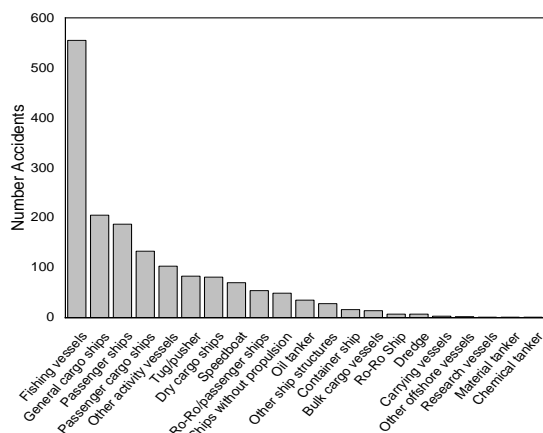

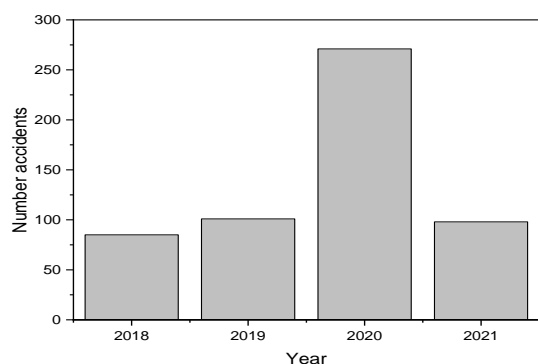**Figure 1.** The number of incidents based on the type of ship

Figure 2. The number of incidents of fishing vessel in 2018-2021 period
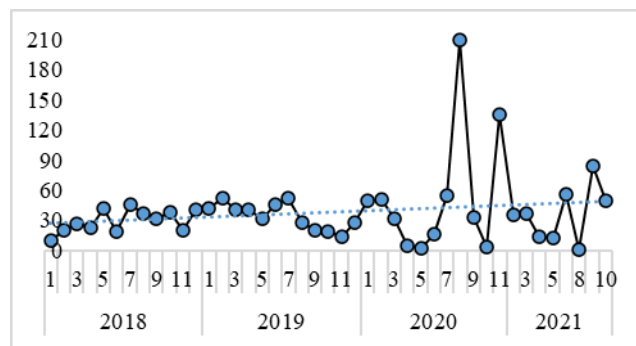

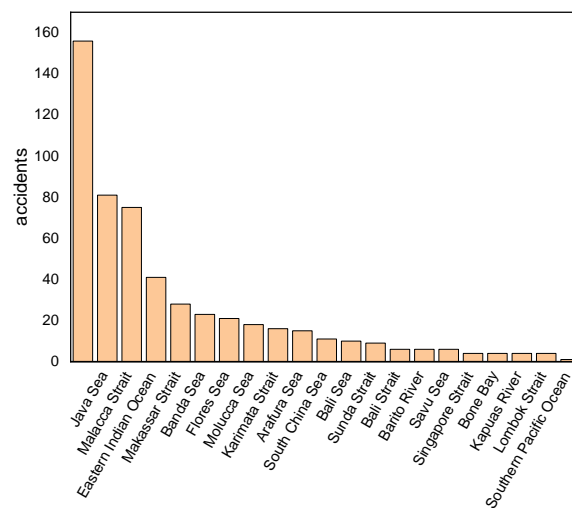**Figure 3.** The number of incidents of Fishing Vessel in 2018-2021 period

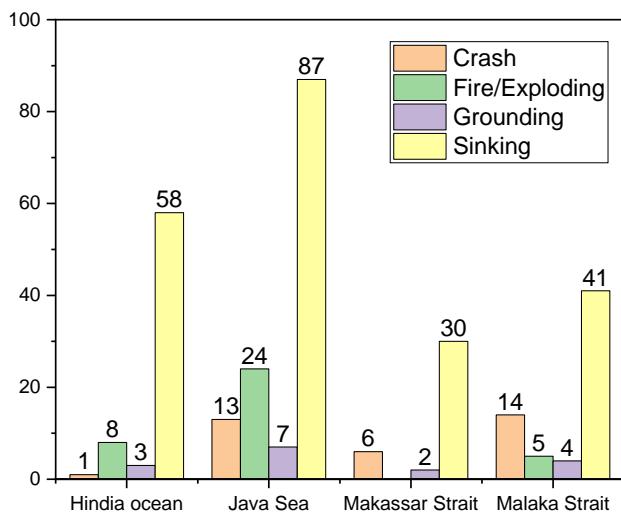**Figure 4.** The number of accidents of fishing boats based on the locations in period 2018-2021

The Java Sea, the Malacca Strait, and the East Indian Ocean, as depicted in Figure 4, have been identified as the primary locations of fishing boat accidents, with the Makassar Strait, the Banda Sea, and the Flores Sea following suit. These areas are crucial maritime routes in Indonesia, serving as vital links between various islands and regions and facilitating international trade and tourism. However, the significance of these waterways is accompanied by notable challenges to maritime safety, including high traffic density, complex hydrographic conditions, environmental risks, piracy, and illegal fishing activities [15]. Enhancing coordination and collaboration among key stakeholders such as government entities, the maritime industry, local communities, and international partners is essential to address these issues effectively. Fishing boat accidents represent a significant concern in Indonesia, with data from the National Transportation Safety Committee (KNKT) revealing that fishing vessels accounted for 31% of all ship accidents between 2018 and 2020, making them the most vulnerable vessel type. During this period, an average of 100 fishers lost their lives or went missing annually due to fishing boat accidents, resulting in a total of 342 casualties [16].

The Java Sea recorded the highest incidents, at 312, followed by the Malacca Strait, Makassar Strait, the Indian Ocean, and the Banda Sea, as shown in Figure 5 for the location. The prevalence of accidents in the Java Sea, Malacca Strait, and Makassar Strait can be attributed to the dense presence of fishing vessels, increasing the likelihood of collisions and other incidents as shown in Figure 6.

Conversely, accidents in the Indian Ocean are often linked to challenging weather conditions, such as large wave heights, exacerbated by the smaller size of fishing vessels operating in the area, rendering them more susceptible to adverse weather. This analysis underscores the necessity for tailored safety measures and regulations specific to each fishing area, considering their distinct challenges. It emphasizes the importance of vessel design, construction standards, and the enhancement of weather forecasting and warning services, particularly in regions prone to severe weather conditions like the Indian Ocean. The insights provided by this comprehensive examination of the regional distribution and causes of fishing vessel accidents offer valuable guidance for policymakers, stakeholders, and researchers in Indonesia.


Figure 5. Typical Maps of the 5 biggest area accidents in Indonesia 2018-2021

Figure 6. The number of accidents based on locations

As shown in Figure 7, the most frequent incidents of fishing boat accidents in Indonesia in the 2018-2021 period were in 2020 from July to October. According to the data from the Indonesian Ministry of Transportation, there were 28 fishing boat accidents in 2020, with 17 of them occurring from July to October [17]. One of the main factors that may have contributed to these accidents was the bad weather and high waves that affected the sea conditions during that period. Indonesia experienced a wet season from October 2020 to April 2021, with heavy rainfall and strong winds in some regions [18]. This may have increased the risk of accidents for fishing boats, especially those not equipped with adequate safety devices and navigational aids. Several factors, such as the monsoon, El Niño, La Niña, and the Indian Ocean Dipole,

influence the wave height and direction in Indonesian waters. These factors can cause temperature, precipitation, and wind pattern variations, affecting the sea surface elevation and wave energy. The study also found that the wave height in Indonesian waters was higher during wet than dry seasons. In April 2021, the BMKG reported a decrease in hot temperatures, potentially linked to the La Niña phenomenon. This event is known for causing increased rainfall and cooler air. Characterized by cooling the sea surface temperature in the central and eastern Pacific Ocean, the La Niña phenomenon can significantly affect atmospheric circulation and rainfall patterns in Indonesia [16].
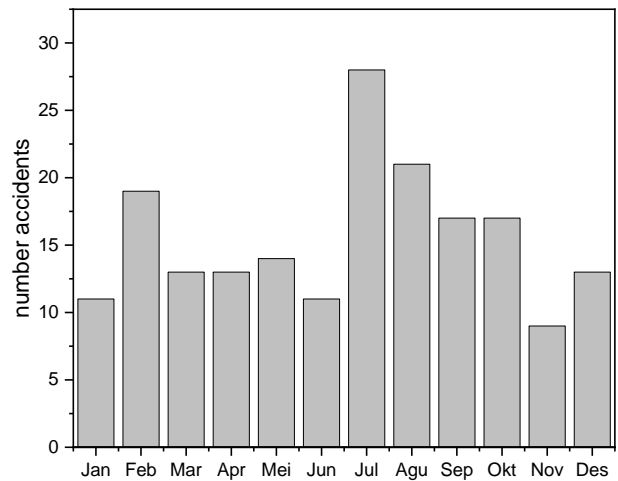
Figure 7. The frequents fishing boat accidents in 2020

The Jakarta Post anticipated that the La Niña phenomenon would peak in December 2020 and January 2021, potentially bringing more rain and storms to Indonesia [19]. The Indonesian fishing industry is dominated by small vessels, typically under 30 GT, which are often traditional and wood-made [9, 20, 21]. However, the existing safety management system has some inadequacies. AIS data in Indonesia does not cover fishing vessels with less than 30 GT capacity [8]. This suggests a significant gap in the safety monitoring of these small vessels. Additionally, while the introduction of Vessel Monitoring Systems (VMS) has increased data availability for vessels above 30 GT [22], the focus remains on larger vessels, leaving smaller vessels less monitored.

Several measures could be considered to improve the safety management system. Given the prevalence of small vessels in the Indonesian fishing fleet, extending safety systems such as AIS and VMS to these vessels is crucial. This could involve developing and implementing systems designed explicitly for small vessels. As many small vessels are traditional and made of wood, efforts could be made to improve their safety features. This could include the addition of modern navigation and communication equipment. Furthermore, it is essential to increase the monitoring of all vessels, regardless of size. This could involve expanding the capacity and coverage of existing monitoring systems. By addressing these inadequacies, it is possible to enhance the safety of Indonesia's fishing industry significantly.

The following are summaries of accidents in July 2020, which recorded the maximum number of accidents for 2018-2021:

- Benoa Waters: A fisherman's boat capsized, resulting in one fatality and one injury.

- Tulang Bawang: A fishing boat sank due to waves, leading to 20 crew members drowning, two fatalities, and one missing crew member found headless.
- Komponeone Waters: A longboat carrying 21 people sank due to waves and water intake, but all passengers survived.
- Binongko Strait: A ship's engine malfunctioned, drifted for five days, broke apart, and sank on its starboard hull.
- Lightning Strike: A ship was struck by lightning and broke apart at night while a crew member was repairing the exhaust pipe.
- Coal Barge Incident: On its way home, a fishing boat was hit and run by a coal barge, but all 16 crew members survived.
- Ulee Lheue Waters: A fishing boat carrying 9 people capsized, resulting in two fatalities.
- Return to Tegal: A fishing boat leaked and sank on its way back, drowning two out of 13 crew members who were suspected to be exhausted and lacked help.
- Ayer Island: A wooden boat carrying 5 fishermen sank due to a leak and was not equipped with a life jacket.
- Jetis Waters: A fisherman drowned when hit by a wave while returning to sea.
- High Waves Incident: A fisherman's boat capsized in high waves after he was pulled by a fish he had caught.
- Trawl Buoy Incident: A fisherman drowned while reaching for a trawl buoy.
- Nisel Waters: A fishing boat carrying 9 fishermen was lost in a storm.
- Dewakang Lompo Island: A Torani fish egg searcher with two people overturned.
- Sore Island: Two fishermen were hit by a storm and capsized in their canoes but managed to call their families and reach the coast.
- Sumba Sea: Five fishermen were rescued by another ship after their boat sank but faced high waves on their way to Sinjai.
- Bagansiapiapi Waters: Five fishermen were found and rescued by a tanker after their boat sank.
- Panjang Island Waters: Six fishermen went fishing but were hit by a strong wind, which caused their boat to take on water.
- Ngrenehan Beach Waters: Three fishermen capsized after their boat engine malfunctioned, and a big wave hit them.
- Paotere Port to Selayar Port: A boat leaked and sank on its way.
- Eretan Waters, Indramayu Regency: A boat sank and was helped by four other ships.
- Strong Winds Incident: A fisherman fell and was lost in solid winds while his two colleagues survived.
- Leaking Canoe Incident: A fisherman drowned in a leaking canoe as he could not swim.
- Overturned Fishing Boat: A fishing boat overturned and killed one fisherman while three others survived.
- Kolong Tanjung Balai Karimun Sluice Gate: A shark-taking ship caught fire and sank after refuelling due to a spark in the engine exhaust.

Some possible factors of fishing vessel accidents and explanations from the evidence of fishing vessel accidents in July 2020 from the literature review:

Human factors: Human factors are the most common and influential factors in fishing boat accidents, as they involve the actions, decisions, behaviours, attitudes, skills, and knowledge of the crew members, operators, owners, managers, and other stakeholders of fishing vessels. Human factors can affect the safety performance of fishing vessels in various ways, such as operator inattention, operator inexperience, improper lookout, lack of training, fatigue, alcohol or drug use, communication errors, non-compliance with rules or procedures, poor judgment, risk-taking, stress, or distraction. Human factors can also interact with other factors, such as weather conditions, technical failures, or environmental hazards, to increase the likelihood or severity of accidents. Studies by research have shown that human decision-making in response to weather conditions can contribute to the severity and occurrence of these incidents [23, 24]. Furthermore, a study by Sánchez-Beaskoetxea et al. [25] suggests that while human error is often involved in marine accidents, the blame does not always lie with the crew, highlighting the complexity of human factors. These factors can include errors made by the crew and other individuals involved, such as pilots and company personnel. These are accidents that are caused by human error, negligence, or misconduct, such as poor judgment, lack of skills, fatigue, distraction, or violation of rules. The data from KNKT regarding the accidents involving fishing vessels in July 2020 are as follows.

- A fisherman's boat capsized in high waves while he was pulled by a fish that he caught. (The fisherman should have released the fish or cut the line to avoid being dragged by it.)
- A fishing boat was hit and run by a coal barge on its way home, but 16 crew members survived. (The coal barge driver should have stopped and helped the fishing boat or avoided hitting it in the first place.)
- A ship's engine malfunctioned and drifted in the Binongko Strait for five days before breaking apart and sinking on its starboard hull. (The ship's crew should have checked and maintained the engine regularly or called for help when it broke down.)
- A shark-taking ship caught fire and sank after refuelling at Kolong Tanjung Balai Karimun Sluice Gate due to a spark in the engine exhaust. (The ship's captain should have turned off the engine and followed the safety procedures when refuelling.)

Weather conditions: Weather conditions significantly impact the safety of fishing boat operations [26]. Studies have found that certain weather factors affect the severity of fishing incidents, and fog significantly influences the occurrence of sea casualties for fishing boats [27]. Extreme weather conditions increase incident rates, such as low air temperature, ice presence, strong winds, and high Laplacian pressure. Certain weather factors significantly influence maritime incidents' occurrence, rate, and consequences [28]. These conditions influence the occurrence, rate, and severity of incidents, affecting the overall safety of commercial fishing operations [29]. Weather conditions can vary depending on the season, location, time of day, or climate change. Weather conditions can also change rapidly and unexpectedly, posing difficulties for forecasting and planning. Therefore, weather conditions should be monitored and considered carefully to ensure the safety of fishing vessels and crew members. These accidents caused by natural phenomena, such as storms, winds, waves, lightning, or currents, make the sea conditions dangerous or unpredictable. The data from KNKT regarding the accidents involving fishing vessels in July 2020 are as follows:

- A fishing boat with 9 fishermen was lost in a storm in

Nisel waters. (The storm was a natural hazard the fishermen could not avoid or control.)

- A ship was struck by lightning and broke apart in the middle of the night while a crew member was repairing the exhaust pipe. (The lightning was a natural phenomenon that the ship could not prevent or predict.)
- Two fishermen were hit by a storm and capsized in their canoes, but they managed to call their families and reach the coast of Sore Island. (The storm was a natural event that the fishermen could not foresee or escape.)
- A fisherman drowned in Jetis Waters when he was hit by a wave while returning to sea. (The wave was a natural force the fisherman could not resist or overcome.)

Technical factors: Technical factors, including the design, construction, maintenance, equipment, and systems of fishing vessels, significantly influence fishing boat accidents. Previous studies have shown that these factors can lead to various failures, such as machinery, electrical, structural, and others. These failures can significantly impact the severity and occurrence of incidents, as well as the safety and effectiveness of the crew. Therefore, regular checks and improvements of these technical factors are essential to ensure the safety of fishing vessels and crew members [30-34]. Examples of these accidents from the accidents of fishing vessel evidence in Juli 2020 are:

- A fishing boat leaked and sank on its way back to Tegal, drowning two crew members out of 13, who were suspected to be exhausted and lacked help. (The leak was a technical problem that the fishing boat could not fix or cope with.)
- Three fishermen capsized in Ngrenehan Beach waters after their boat engine malfunctioned and a big wave hit them. (The engine malfunction was a technical issue the boat could not resolve or handle.)
- A wooden boat with five fishermen sank near Ayer Island due to a leak. The boat was not equipped with a life jacket. (The leak was a technical fault that the wooden boat could not repair or deal with.)
- A boat leaked and sank from Paotere Port to Selayar Port. (The leak was a technical failure that the boat could not correct or manage.)

The design and construction of fishing vessels, particularly in Indonesia, are crucial for safety and functionality. Traditional boats often lack safety features such as double hulls and watertight bulkheads, posing survivability challenges [35]. Additionally, many lack essential safety equipment like fire extinguishers, increasing fire risks. Therefore, the design and construction standards should include detailed technical explanations and implementation details for these safety features. Furthermore, these standards should consider specific vessel design criteria and dimensions to optimize performance in various sea conditions.

Environmental factors: Environmental factors play a crucial role in influencing fishing boat accidents, with natural or artificial features and conditions of waterways significantly impacting maritime safety. Previous studies [27-31] have highlighted the diverse challenges posed by environmental factors such as shallow waters, submerged obstacles, marine debris, marine traffic, marine protected areas, pollution, and climate change, emphasizing the need for regular assessments and effective management of these factors. The dynamic nature of these environmental elements, characterized by rapid and unpredictable changes, complicates forecasting and planning efforts, ultimately affecting the frequency and severity of fishing boat accidents. Therefore, proactive monitoring and strategic management of environmental factors are imperative to safeguard fishery resources' sustainability and ensure the safety of fishing vessels and crew members. In order to enhance weather forecasting and warning services for Indonesian fishermen, it is essential to improve forecast communication. Research suggests that presenting forecasts in a tabular format, preferred by fishermen [36], could facilitate better understanding and utilization of weather information. Moreover, integrating local knowledge into official forecasts can enhance their acceptance among fishermen who often rely on their observations and traditional beliefs [37]. Additionally, efforts to enhance the accuracy of regional weather forecasts, particularly in diverse geographical settings like Indonesia [38], are crucial. These initiatives promote fishermen's increased adoption of official forecasts, fostering safer fishing practices and potentially reducing weather-related incidents. By ensuring the relevance and reliability of forecasts, decision-making processes can be better informed, contributing to improved safety measures and risk mitigation strategies in the fishing industry.

The data from KNKT regarding the accidents involving fishing vessels in July 2020 are as follows:

- Waves hit a fishing boat and sank in Tulang Bawang, drowning 20 crew members, two of whom died, and one of whom was missing and later found headless. The waves were caused by environmental factors such as tides, currents, or wind patterns.
- A longboat with 21 people on board sank in Komponeone Waters due to waves and water intake, but everyone survived. The waves were caused by environmental factors such as tides, currents, or wind patterns.
- Six fishermen went fishing in Panjang Island waters but were hit by a strong wind that made their boat take on water. The wind was caused by environmental factors such as air pressure, temperature, or humidity [39].
- A fishing boat with 9 people on board capsized in Ulee Lheue Waters, killing two passengers. The capsize was caused by environmental factors such as water depth, salinity, or density [40].
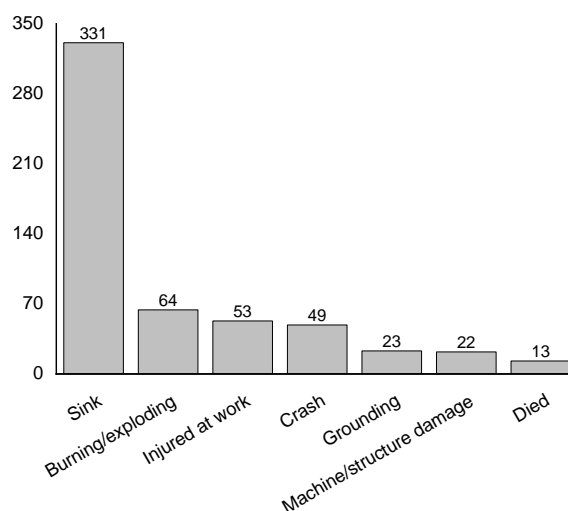
Figure 8. The types of fishing vessel accidents

Overall, from the data collected, the types of fishing vessel accidents that occurred during 2018-2021 are shown in Figure

8. Based on the data, most fishing boat accidents from 2018-2021 were due to weather conditions, explicitly tilting/sinking incidents, accounting for approximately 60.0% of all incidents. Technical factors, such as boats being burned/exploded and machinery/equipment/structure damage, contributed to about 15.6% of the incidents. Human factors, including deaths/injuries while working and people falling into the sea, were responsible for around 12.0% of the incidents. Lastly, environmental factors, represented by collision/bump incidents, comprised approximately 8.9% of the total incidents. Please note that these are general classifications, and the actual cause of each incident could vary. A detailed investigation of each incident would be necessary for a more accurate classification.

Various factors influence maritime accidents, and their proportions vary based on data sources, accident definitions, and analysis methods. Dominguez-Péry et al. [41] found that human factors accounted for 58% of root causes in maritime accidents, followed by socio-technical (25%), individual/cognition-related (11%), and human resources/management factors (6%). They proposed a framework to understand the role of human error in maritime accidents. Celik and Cebi [42] analyzed 17 years of Lloyd's Register Fairplay (LRF) accident data and found that technical factors accounted for 41% of causal factors, followed by human (32%), environmental (16%), and operational factors (11%). They developed a Human Factors Analysis and Classification System (HFACS) framework to identify failures contributing to maritime accidents. Maternová [43], analyzing 10 years of LRF and other sources' accident data, found that weather conditions accounted for 31% of accident causes, followed by human error (28%), technical failure (18%), and others. They created a Maritime Security Incidents Data Set (MSIDS) to provide an overview of maritime security incidents. Similarly, Hetherington et al. [44] found that weather conditions accounted for 30% of accident causes and examined the effect of weather factors on the severity of fishing boat accidents in Atlantic Canada. Data on maritime accidents reveal differences in accident factors between Indonesia and other countries [45, 46]. The following are various factors influence maritime accidents:

- Human Factors: These account for a higher proportion of fishing vessel accidents in developing countries, potentially due to inadequate training, education, and awareness among fishers and a lack of enforcement of safety regulations. Dominguez-Péry et al. [41] and Celik and Cebi [42] reported human factors as 58% and 32% of the root causes of maritime accidents, respectively.

- Technical Factors: These account for a higher proportion of accidents in developed countries, possibly due to the complexity of fishing vessels and equipment requiring more maintenance and inspection. Celik and Cebi [42] and Dominguez-Péry et al. [41] reported technical factors as 41% and 25% of the root causes of maritime accidents, respectively.

- Environmental Factors: These account for a similar proportion of accidents in both developing and developed countries due to exposure to various sea hazards. Celik and Cebi [42] and Maternová [43] reported that environmental factors account for 16% and 31% of accident causes, respectively.

- Operational Factors account for a lower proportion of accidents in both developing and developed countries, potentially due to the implementation of safety management systems on board fishing vessels. Celik and Cebi [42] and Wu et al. [24] reported operational factors as 11% and 12% of the accident causes, respectively.

In conclusion, while there is no definitive answer to the proportion of ship accidents caused by different factors, it is evident that human factors, technical factors, and weather conditions are among the most common and influential factors in maritime accidents. Therefore, a holistic and systemic approach to maritime safety, considering individual components and their interactions, is crucial. Fishing vessel safety is a critical concern in fisheries, particularly in Indonesia, where traditional wooden boats are prevalent. These vessels are susceptible to inclement weather, rough seas, fire, explosion, collision, grounding, and mechanical or structural failure. Data indicates that Indonesia's most common fishing vessel accident from 2018-2021 was tilting or sinking, suggesting urgent attention is needed to address stability and integrity issues. Factors contributing to these incidents include overloading, improper stowage, lack of watertightness, inadequate maintenance, and human error [46]. Adverse weather conditions can exacerbate these risks, underscoring the need for improved design and construction standards for fishing vessels and enhanced weather forecasting and warning services for the fisheries sector [47]. Other types of accidents during this period include burning or exploding, work-related injuries or fatalities, crashing, grounding, machine or structure damage, and fatalities due to falling into the sea. These incidents can result from various causes such as fuel leakage, electrical short circuits, poor ventilation, lack of fire-fighting equipment, unsafe working practices, fatigue, lack of communication, navigational errors, insufficient water depth, poor seamanship skills, equipment failure, corrosion, wear and tear, lack of personal protective equipment, slippery decks, and strong currents [48-51] Implementing safety management systems on board fishing vessels can help prevent or mitigate the effects of these accidents and enhance the safety culture among fishers.

Since the start of the new millennium, there has been a significant reduction in fishing vessels. The 2022 SOFIA report indicates that the global fishing fleet decreased by nearly 10% to 4.1 million vessels from 2015 to 2020. Out of these, only around 45,000 vessels were more significant than 24m, while the majority (81%) were small open boats less than 12m in length. This predominance of small open boats, primarily in Asia and Africa, is a crucial contributor to safety issues in the fishing industry [52]. Even though the risks and dangers of the sea are well-known in these regions, there is a lack of regulations or mandatory safety requirements for these boats and their crews. Most countries' construction and equipment regulations typically apply only to larger vessels over 24 m, and adherence by small boat operators is often voluntary [53]. The crews of these small boats are mainly unskilled workers, needing more seamanship and fishing-specific knowledge and awareness of potential hazards and dangers [54]. Driven by the constant need for profitable catches to maintain economic viability, these crews often take hard-to-evaluate risks. They frequently venture too far from the coast, go to sea even when storms are forecasted, and often operate poorly maintained and inadequately marked boats, putting them at constant risk of capsizing or collision with larger ships [55].

Table 1. The factor, types, mitigations and regulations all of the case incidents on the sea

Factors	Types	Mitigation/Prevention	Regulations
Bad weather, rough seas, strong winds, high waves, heavy rain, thunderstorms	Tilting/Sinking, Crashing, Grounding, dying due to falling into the sea	Improve weather forecasting and warning services, avoid sailing in adverse conditions, ensure vessel's buoyancy, trim and stability	SOLAS COLREG
Fire, explosion, fuel leakage, electrical short circuit, poor ventilation, lack of fire-fighting equipment	Burning/Exploding, Dying/Injuring at work	Implement safety management systems, conduct risk assessments, follow safety procedures, install fire detection and suppression systems, maintain fuel and electrical systems	SOLAS, ISM, MARPOL
Collision, navigational errors, lack of communication, poor seamanship skills	Crashing, Tilting/Sinking, Burning/Exploding, Dying/Injuring at work	Implement safety management systems, conduct risk assessments, follow safety procedures, use collision avoidance systems, maintain communication systems, train seafarers	SOLAS, ISM, COLREG, STCW
Grounding, insufficient water depth	Grounding, Tilting/Sinking	Implement safety management systems, conduct risk assessments, follow safety procedures, use navigational aids and charts, avoid shallow waters	SOLAS, ISM, COLREG
Mechanical or structural failure, equipment failure, corrosion, wear and tear	Machine/Structure damage, Tilting/Sinking, Burning/Exploding	Implement safety management systems, conduct risk assessments, follow safety procedures, improve design and construction standards of vessels and equipment, conduct regular inspections and maintenance	SOLAS, ISM, MARPOL, LOADLINE
Overloading, improper stowage, lack of watertightness	Tilting/Sinking	Implement safety management systems, conduct risk assessments, follow safety procedures, improve design and construction standards of vessels and equipment, comply with load line regulations	SOLAS, ISM, MARPOL, LOADLINE
Unsafe working practices, fatigue, human error	Dying/Injuring at work, Dying due to falling into the sea	Implement safety management systems, conduct risk assessments, follow safety procedures, train seafarers, provide personal protective equipment, ensure adequate rest periods	SOLAS, ISM, STCW, ILO conventions [38]
Lack of security measures, piracy, terrorism, sabotage	Burning/Exploding, Tilting/Sinking, Dying/Injuring at work, Machine/Structure damage	Implement security management systems, conduct security assessments, follow security procedures, install security equipment, train seafarers, cooperate with law enforcement agencies	SOLAS[1], ISPS [39]

Improving fishing vessel safety in Indonesia is challenged by low compliance with safety rules on ships, potentially due to factors such as lack of awareness, knowledge or motivation, economic pressures, social norms, or enforcement difficulties. Designing and implementing behaviour change interventions targeting these factors can help reduce illegal fishing behaviours. Such interventions include awareness campaigns, education and training, incentives and rewards, feedback and monitoring, social marketing, peer support, role models, and enforcement and sanctions [56, 57]. These interventions can enhance understanding of the benefits of safety rule compliance, skills and confidence in applying safety measures, motivation to adopt safe behaviours, perception of social norms and expectations, and compliance with legal obligations.

Table 1 summarizes the main factors that cause fishing vessel accidents, the types of accidents that result from these factors, and the mitigation or prevention measures that can be taken to reduce the risk and impact of these accidents. The table also lists the relevant regulations that govern and guide fishing vessel safety at the international level. These regulations are issued by various organizations such as the International Maritime Organization (IMO), the International Labor Organization (ILO), and the Food and Agriculture Organization of the United Nations (FAO).

The International Convention for the Safety of Life at Sea (SOLAS) is a critical maritime safety standard that significantly prevents fishing boat accidents. SOLAS provides a comprehensive set of safety standards and regulations, including requirements related to the construction, equipment, and operation of ships, designed to ensure the safety of the vessel and its crew. Previous studies have highlighted the importance of SOLAS in enhancing maritime safety. These

studies have shown that adherence to SOLAS requirements, such as the use of advanced navigation systems and the implementation of a working legal framework of reference, can significantly reduce the occurrence and severity of fishing boat accidents [58-60].

The International Regulations for Preventing Collisions at Sea (COLREGs) are rules established by the International Maritime Organization (IMO) to prevent collisions between vessels at sea. Studies by Morel and Chauvin [60], Chong [61], Du et al. [62], Ugurlu and Cicek [63], and Acar et al. [64] have highlighted the significant role of COLREGs in preventing fishing boat accidents. These studies have shown that adherence to COLREGs, such as the proper use of lights and shapes on small fishing vessels and vessels being towed, can significantly reduce the occurrence and severity of fishing boat accidents [61-65]. Furthermore, the development of a COLREG-compliant ship collision alert system for stand-on vessels has been shown to enhance maritime safety. However, violations of COLREG rules have been identified as a significant factor contributing to ship collisions, indicating the need for improved maritime education and training on correctly applying these rules.

The International Safety Management (ISM) Code is a crucial maritime safety standard established by the International Maritime Organization. It requires all shipping companies operating certain types of vessels to establish safety management systems. Previous studies have highlighted the significant role of the ISM Code in preventing fishing boat accidents [66-69]. These studies have shown that proper and effective implementation of the ISM Code, such as introducing safety management systems for deep-sea fishing vessels, can significantly reduce the number of injuries, serious injuries,

fatalities, and other incidents threats during vessel operation in maritime shipping. Furthermore, the ISM Code has been found to impact the maritime field extensively, including improving maritime safety and preventing marine pollution from ships. The International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel (STCW-F) is a critical maritime safety standard. Studies by Cho et al. [69], Zoolfakar et al. [70], and Zoolfakar et al. [71] have highlighted the significant role of the STCW in preventing fishing boat accidents. These studies have shown that proper and effective STCW implementation, such as improving the introductory safety training course and regulation for fishing vessel seafarers, can significantly reduce the occurrence and severity of fishing boat accidents. However, issues faced by fishermen on the implementation of STCW-F, such as cost, awareness, attitude, government/fisherman association role, and lack of facilities, need to be addressed to ensure its effective implementation [70-72].

The International Convention for the Prevention of Pollution from Ships (MARPOL) is a critical international marine environmental convention designed to minimize sea pollution, including dumping, oil, and exhaust pollution. Its role in preventing fishing boat accidents is significant. Mata-Álvarez-Santullano and Souto-Iglesias [72] discussed the impact of fishing effort control policies on ship stability, indirectly acknowledging the role of MARPOL in promoting environmentally safe fishing practices. Marchenko et al. [73] examined maritime activity in the high north, highlighting the importance of adhering to international conventions like MARPOL to mitigate unwanted incidents and risk patterns. Sahatjian [74] discussed the criminalization of maritime accidents and MARPOL violations in the United States, emphasizing the legal implications of not adhering to MARPOL regulations. Therefore, MARPOL plays a crucial role in promoting environmentally safe practices, thereby indirectly contributing to the prevention of fishing boat accidents [73-75]. The Load Line Standard, also known as the Plimsoll Line, is a maritime safety regulation that sets the minimum allowable freeboard (vertical distance between the waterline and the deck) for ships, limiting the maximum load a ship can carry [76].

Fishing vessel accidents are a severe problem for the fisheries sector, especially in developing countries, where most fishers are small-scale and operate with low safety standards and regulations. According to a study by FAO [54], fishing is one of the most hazardous occupations in the world, with an estimated 24,000 fatalities per year. The study also found that the fatality rate of fishers in developing countries is 10 to 20 times higher than that of fishers in developed countries. Some of the factors that contribute to this high fatality rate are:

- The lack of adequate design, construction, and equipment for fishing vessels can affect their stability, buoyancy, watertightness, fire protection, and navigation.
- Lack of safety management systems, risk assessments, safety procedures, emergency plans, training programs, safety inspections, and accident reporting on board fishing vessels.
- Lack of enforcement of safety regulations and standards by the authorities and lack of compliance by the fishers themselves.
- Exposure to various hazards at sea, such as bad weather, rough seas, strong winds, high waves, heavy rain, thunderstorms, fire, explosion, collision, grounding,

mechanical or structural failure, overloading, improper stowage, unsafe working practices, fatigue, human error, piracy, terrorism, sabotage, etc.
- Lack of access to medical care and rescue services in case of accidents or emergencies.

Improving fishing vessel safety in Indonesia involves addressing factors such as lack of awareness, knowledge, motivation, and difficulties in law enforcement Behavioral interventions, such as awareness campaigns, education, and training, can help increase compliance with safety regulations [77-83]. Strengthening law enforcement mechanisms and addressing organizational issues can also enhance safety outcomes [84, 85] Implementing rights-based fisheries management could address issues related to competitive fishing practices [81]. Analysis of successful cases can provide valuable insights into the effectiveness of these interventions.

The limitations of this research are primarily its focus on Indonesia, which may not reflect the broader global context, potentially affecting the generalizability of the findings. Not all variables that could impact fishing vessel safety, such as regulatory differences, cultural practices among fishermen, and economic variations across countries, were considered. Furthermore, the possibility of reporting bias exists within the data, as unreported ship accidents, particularly involving small fishing vessels, are likely given Indonesia's vast maritime geography. For future research directions, a comparative study across various countries would be beneficial to gain a comprehensive understanding of fishing vessel safety on a global scale. Longitudinal research assessing the effectiveness of newly proposed safety management systems would provide valuable insights into their practical impact. Lastly, prioritizing investigations into vessel safety improvements can lead to significant advancements in the field.

4. CONCLUSIONS

In conclusion, the safety of fishing vessels, particularly in Indonesia, is a critical concern that requires urgent attention due to the common accidents of tilting or sinking, often attributed to human, technical, and environmental factors. Human factors, such as lack of training and awareness, are significant, particularly in developing countries, while technical factors, like vessel and equipment complexity, are more prevalent in developed nations. Environmental factors, such as adverse weather conditions, pose risks universally. Enhancing safety necessitates a holistic approach involving improved design and construction standards, advanced weather forecasting, and safety management systems on board vessels. However, the challenge lies in low compliance with safety rules, which can be addressed through behaviour change interventions targeting awareness, knowledge, motivation, economic pressures, and social norms, ultimately reducing sea-related casualties and property loss, enhancing fishing operations' safety and sustainability, and benefiting the fishing community's well-being. This discussion stresses the importance of ongoing research and interventions in this domain, with innovative aspects of the study focusing on a comprehensive strategy to enhance fishing vessel safety in Indonesia by identifying challenges and proposing tailored behavioral interventions. The research also underscores the significance of integrating local knowledge into official forecasts, improving communication, and enhancing regional weather forecast accuracy. The potential impact on future

policymaking is substantial, as the findings could guide the development of policies fostering a safety culture within fishing organizations, strengthening law enforcement, and enhancing safety regulation compliance. Additionally, the research advocates for rights-based fisheries management to address competitive fishing practices and emphasizes the analysis of successful cases to provide insights for effective interventions, guiding future policymaking in the fishing industry. Overall, this research has the potential to improve fishing vessel safety in Indonesia and globally significantly.

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