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Quantitative risk assessment of industrial accidents among fishermen in purse seine fisheries

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Abstract

The risk of industrial accidents among fishermen in purse seine fisheries was assessed through the analysis of 1,478 approved industrial accident insurance claims over the past five years. The impact of risk factors specified in these insurance documents on accident types was evaluated through a chi-square test applied to three categories of purse seine fisheries: coastal, small-scale, and large-scale. Risk assessment was performed using a Bayesian network based on the formal safety assessment proposed by the International Maritime Organization. Based on factors identified as significant by the chi-square test, a Bayesian network was constructed to assess the quantitative risk of major industrial accident types within each purse seine fishery category. Time of occurrence, work processes, and environmental causes were significant risk factors in coastal purse seine fisheries. In small-scale purse seine fisheries, accident types were significantly associated with environmental causes, with hull-related slips/bumps and gear-related hits/entrapments identified as the major risks. Large-scale purse seine fisheries were analyzed based on vessel type: main boats, light boats, and carriers. Main boats and carriers were significantly associated with work processes and environmental causes, while light boats showed significant associations with fishermen's nationality, work processes, and environmental causes. Main boats had the highest risk during fishing, with hull-related slips/bumps and gear-related accidents as the major threats. Light boats posed a 34.68-fold higher risk to nationals compared to foreigners. Fishing presented a higher risk, though it was not significantly different from sailing or maintenance. Carriers were the most dangerous during catch unloading. Hull-related environmental causes were the major risk, significantly outweighing risks from fishing gear (20.70-fold), machinery (8.75-fold), and external causes (17.26-fold). This study provides a foundation for implementing risk mitigation strategies in purse seine fisheries by identifying key accident-causing factors and presenting quantitative risk assessments based on fishery category and vessel type.

Keywords: Quantitative risk assessment, Coastal and offshore fishery, Purse seine, Bayesian network, Chi-square test

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Introduction

Marine fishing is among the most hazardous occupations due to the exceptionally high mortality rates recorded among fishermen (Jaremin & Kotulak, 2004; Jin & Thunberg, 2005). In 2022, the accident rate in South Korean fisheries was 10.60%, significantly exceeding the overall industrial accident rate of 6.46% (MOEL, 2023). Fisheries involve both sailing and fishing operations and expose fishermen to a variety of risks. To prevent and mitigate maritime accidents, the South Korean government amended the Act on the Promotion of Safety and Health for Fishermen and established specific safety measures for fishing vessels. In particular, Article 28 mandates that comprehensive risk assessments be conducted to identify the hazards associated with tasks and work activities of fishermen.

Since 2002, the International Maritime Organization (IMO) has recommended the formal safety assessment (FSA). The FSA framework includes five stages: hazard identification, risk assessment, risk control options, cost-benefit analysis, and decision-making. The second stage, risk assessment, introduces nine techniques for scientific and quantitative risk assessment (IMO, 2018). Extensive research on maritime accidents has been conducted worldwide, with emphasis on fishing vessels due to their inherently high risks. Prior studies have explored a range of factors influencing fishing vessel accidents, including fishing vessel accident probabilities based on variables such as wind speed, vessel size, fishing area, season, and vessel type using a logistic regression model (Jin & Thunberg, 2005); accident severity in relation to time, wind speed, vessel age, and distance from shore (Jin, 2014); capsize scenarios for small fishing vessels modeled with Bayesian networks (Obeng et al., 2022); effects of time, fishing area, and human factors on vessel accident risk (Lazakis et al., 2014); and accident reports such as fatal incidents on Danish fishing vessels (Laursen et al., 2008).

Bayesian networks are widely applied in reliability, risk analysis, and maintenance areas due to their capacity to model probabilistic data with interdependent events, which make them well-suited for risk analysis (Weber et al., 2012) and supports the quantitative modeling of marine accidents and facilitate analysis of human and organizational factors (Zhang & Thai, 2016).

This study aimed to quantitatively assess the risk of accidents among fishermen in coastal and offshore purse seine fisheries in South Korea. To achieve this, this study quantitatively analyzed approved accident insurance claims from 2018 to 2022. Chi-square tests were conducted on factors that were previously associated with fishing vessel safety to determine their correlations with industrial accidents among purse seine fishermen in coastal waters in South Korea. To quantitatively assess accident risk of purse seine fisheries, a Bayesian network, aligned with the IMO's FSA framework, was constructed based on the correlated factors. This quantitative risk assessment aims to support safer and more sustainable purse seine fisheries in South Korea.

Materials and Methods

Fishing vessel and fishermen accident insurance

Purse seine fishing is a technique for catching fish and this involves locating and identifying schools of fish and then encircling them with a net called seine to block escape routes. In recent years, there has been a growing tendency to equip vessels with excessive gear or load large fish schools to maximize catches, increasing vessel weight and raising the center of gravity, which can lead to vessel instability. Fishing vessels also use heavy equipment like ball rollers or power blocks to haul in the nets encircling fish (NIFS, 2018). Auxiliary vessels in the fleet have specific roles, each of which has its unique risks.

Accurate data is crucial for reliable quantitative analysis of industrial accidents among fishermen. To ensure data accuracy, this study utilized approved accident insurance claim records from 2018 to 2022 under the Fishing Vessel and Fishermen Accident Insurance scheme. The data from this insurance scheme, in effect since 2004, includes detailed records on vessel type, size, age, fishermen information, and accident specifics, making it a trusted source for quantitative risk assessment of industrial accidents.

Influential risk factors

Influential risk factors are variables that impact the safety of fishing vessels (Wang et al., 2023). The accident insurance claim records contained information on a wide range of influential factors, including the location of industrial accident; age of vessel; gross tonnage; date and time of the incident; and details of the injured fishermen, such as age, nationality, and onboard position. Thorough documentation of work processes and environmental conditions during the incident provides essential data for identifying influential risk factors. Accident types were classified according to the 41 distinct codes defined by the Korean Ministry of Employment and Labor for industrial accidents.

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Chi-square test

A chi-square test was used to assess the significance of the factors related to industrial accidents among fishermen in relation to the types of industrial accidents in coastal and offshore purse seine fisheries in South Korea. This test evaluates the statistical significance of the difference between observed and expected frequencies and is well-suited for analyses of qualitative data (Güngör & Bulut, 2008; McHugh, 2013). One major advantage of the chi-square independence test is its applicability to both categorical and numerical data (Burns & Dobson, 1981; Sirkin, 2006). The hypotheses for the chi-square test are as follows (McHugh, 2013; Sirkin, 2006):

- · Null hypothesis (H_0): the two variables are independent.
- · Alternative hypothesis (H_1 or H_a): the two variables are interdependent.

In the chi-square test, a significance level (p) is typically set at 0.05; a p-value above 0.05 supports the null hypothesis (H_0), whereas a p-value below 0.05 supports the alternative hypothesis (H_1 or H_a).

Bayesian network

A Bayesian network, also known as a belief network or probabilistic directed acyclic graph (DAG), visually represents the joint probability distribution of a selected set of variables (Pearl, 1988). This model is used to represent conditional probabilities among variables that consist of cause and effect nodes. It is a DAG that represents dependencies between variables using directional edges. It has the advantage of prediction through prior probability and posterior inference. Recently, there has been increasing interest in using this method to model phenomena that are related to human and organizational factors (Trucco et al., 2008). Bayesian networks have been widely used as a modeling approach for building expert systems that include uncertainty and have also been used in various maritime safety-related studies (Hänninen & Kujala, 2014; Hänninen et al., 2013 ; Trucco et al., 2008).

To apply a Bayesian network, the conditional probability, that is, the probability of an event occurring given that another event has already occurred, must be understood. Specifically, the probability of event A occurring because event B has occurred is known as the "conditional probability of A given B," denoted as P(A|B). Note that P(A|B) can vary with event B and is generally not equal to P(B|A). This relationship between prior and posterior probabilities of two random variables defines the connection between conditional and marginal probabilities (Eq. 1):

$$P(A \mid B) = (P(A \cap B)) / P(B) = (P(B \mid A)P(A)) / P(B) \quad (1)$$

where P(A) is the prior probability of event A occurring before B, P(B) is the prior probability of event B occurring, P(A | B) is the joint probability of both events A and B occurring, P(A | B) is the posterior probability of A given B, and P(B | A) is the likelihood function of A given B (Kitson et al., 2023). For example, if the industrial accident rate in coastal and offshore fisheries is denoted as P(I) and the industrial accident rate in stow net fisheries is denoted as P(P), it can be expressed as follows (Eq. 2).

$$P(P \mid I) = (P(P \cap I)) / P(I) = (P(I \mid P)P(P)) / P(I) \quad (2)$$

The probability of an industrial accident occurring in purse seine fisheries, given that an industrial accident has occurred in coastal and offshore fisheries, can be inferred using the following: P(I) represents the prior probability of an industrial accident occurring in coastal and offshore fisheries; P(P) is the prior probability of an industrial accident occurring in purse seine fisheries; P(I∩P) is the joint probability of both events occurring; P(P | I) is the posterior probability of an industrial accident occurring in purse seine fisheries given that one has occurred in coastal and offshore fisheries; and P(I | P) is the likelihood function for an industrial accident occurring in coastal and offshore fisheries given that one has occurred in purse seine fisheries.

Results and Discussion

Industrial accident statistics in coastal and offshore fisheries

Table 1 summarizes the statistics for insurance subscribers, accident cases, accident rates, fatalities, and fatality rates (deaths per thousand cases). Among the coastal and offshore fisheries in South Korea, purse seine fishing ranked eighth in terms of number of accident insurance subscribers, fourth in industrial accident cases, first in accident rate (9.84%), and second in fatality rate (27.31%), after single trawl fishing. Given these high accident and fatality rates, purse seine fishing was classified as a high-risk sector in coastal and offshore fisheries in South Korea.

Coastal and offshore fisheries in South Korea are classified into two main types: coastal and offshore. Coastal fisheries involve smaller vessels under 10 tons, either non-motorized or powered, whereas offshore fisheries use larger powered vessels

Table 1. Status of industrial accidents in coastal and offshore fisheries (2018–2022)

	Number of insured	Number of industrial accidents	Industrial accident rate (%)	Number of fatalities	Mortality rate (‱)
Gillnet	78,455	3,841	4.90	138	17.59
Compound	37,597	1,551	4.13	35	9.31
Trap	31,288	1,635	5.23	63	20.14
Handline	23,612	430	1.82	23	9.74
Stow net	22,428	1,193	5.32	42	18.73
Danish seine	18,464	508	2.75	26	14.08
Longline	16,402	540	3.29	42	25.61
Purse seiner	15,014	1,478	9.84	41	27.31
Single trawl	8,486	416	4.90	27	31.81
Pair trawl	7,449	392	526	15	20.14
Trawl	6,091	299	4.91	6	9.85

over 10 tons (KLIC, 2024). Purse seine fisheries are similarly divided into coastal and offshore categories, with offshore purse seine fisheries further classified into small-scale and large-scale operations. Purse seine fishing operations generally involve fleets of two or more vessels. Coastal purse seine fisheries operate with one main and one auxiliary vessel. In offshore purse seine fisheries, a large-scale fleet typically consists of one main boat, two light boats, and three carriers, whereas the composition of small-scale fleets varies. Despite the differences in fleet structure, large- and small-scale offshore purse seine fisheries use similar fishing methods (NIFS, 2018). Table 2 shows the industrial accident statistics for each category of purse seine fisheries over the past 5 years. In South Korea, approximately 85% of industrial accidents in purse seine fisheries occurred during offshore operations, with 76% of these incidents taking place in large-scale purse seine fisheries.

Table 2. Status of industrial accidents based on purse seine fishery categories (2018–2022)

	Coastal	Small	Large	Total
Number of accidents	236	118	1,124	1,478
Ratio (%)	15.97	7.98	76.05	100

Influential risk factors

Common industrial accident types in purse seine fisheries included falls, slips, pinning, bumps, hits, collapses, entrapments, and awkward postures. Across purse seine fishery categories, the most common accident types were slips, hits, entrapments, and bumps, although the rankings varied (Table 3). The 10 identified categories of influential risk factors were divided into subcategories, as detailed in Table 4.

Chi-square test results

The results of the chi-square test conducted to analyze the association between the top four accident types and the categories of influential risk factors in purse seine fisheries are shown in Table 5. For coastal and offshore purse seine fisheries, gross

Table 3. Type of industrial accidents based on purse seine fishery categories

	Coastal (numbers, %)		Small (numbers, %)		Large (numbers, %)		Total (numbers, %)	
Slip	66	43.71	39	39.80	288	40.97	393	41.28
Hit	23	15.23	16	16.33	186	26.46	225	23.63
Entangle	39	25.83	19	19.39	95	13.51	153	16.07
Bump	12	7.95	14	14.29	72	10.24	98	10.29
Fall	10	6.62	4	4.08	39	5.55	53	5.57
Awkward posture	1	0.66	6	6.12	23	3.27	30	3.15

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Table 4. Classification of influential risk factors

Influential risk factors	Classification
Fishing area	- East sea
	- West sea
	- South sea
Age of fishing vessel	- Under 5
	- 5–10
	- 10–15
	- 15–20
	- Over 20
Gross tonnage	Under 3
	- 3–10
	- 10–50
	- 50–100
	- Over 100
Month	- Each month
Time of occurrence	- Each 4 h
Age (s)	- Younger than 40
	- 40
	- 50
	- 60
	- 70
	- Over 70
Nationality	- Korean nationals
	- Foreigners
Onboard position	- Captain-equivalent
	- Officer and engineer
	- Head of department
	- Seaman
Work process	- Sailing: S
	- Fishing: F
	- Maintenance: M
	- Catch unloading: C
Environmental cause	- Hull: h
	- Fishing gear: f
	- Machinery: m
	- External cause: e

tonnage, accident time, nationality, onboard position, work processes, and environmental causes were identified as factors significantly associated with accident types. Additional chi-square tests were performed on accident types for each purse seine fishery category (coastal, small-scale, and large-scale) based on these influential factors (Table 6). Within the large-scale purse seine fisheries category, chi-square tests were conducted separately for the main boat, light boats, and carriers to align with distinctions made in the insurance claims.

The p-value obtained from the chi-square test indicates the probability of observing the given data, or something more extreme, under the null hypothesis that there is no association between the variables. A p-value less than 0.05 is typically considered statistically significant, suggesting that the observed association is unlikely to have occurred by chance.

The results of the chi-square test conducted to analyze the association between the top four accident types and the categories of influential risk factors in purse seine fisheries are shown in Table 5. For coastal and offshore purse seine fisheries, gross tonnage, accident time, nationality, onboard position, work processes, and environmental causes were identified as factors significantly associated with accident types ($p < 0.05$ for all). Additional chi-square tests were performed on accident types for each purse seine fishery category (coastal, small-scale, and large-scale) based on these influential factors (Table 6). Within the large-scale purse seine fisheries category, chi-square tests were conducted separately for the main boat, light boats, and carriers to align with distinctions made in the insurance claims.

For coastal purse seine fisheries, accident time of occurrence, work processes, and environmental causes were significantly associated with accident types ($p < 0.05$). For small-scale offshore purse seine fisheries, environmental causes showed a significant association ($p < 0.05$). For large-scale offshore purse seine fisheries, significant associations were observed between accident types and work processes and environmental causes on both the main boats and the carriers ($p < 0.05$), whereas light boats showed significant associations with nationality, work processes, and environmental causes ($p < 0.05$).

Bayesian network construction and analysis results

A Bayesian network was constructed for quantitative analysis using the influential risk factors that were identified as significantly associated with industrial accidents in the chi-square test (Fig. 1). The first node, termed the "root node" in the Bayesian network, represented the overall 5-year accident rate of 4.49% for the coastal and offshore fishing industry. The root node connected to the second node, showing that 10.69% of industrial accidents occurred in purse seine fisheries, establishing a parent-child connection between the root and second nodes. This structure enables inference of the posterior probability of an accident occurring specifically in purse seine fisheries when an industrial accident occurs within the coastal and offshore

Table 5. Chi-square test on types of industrial accidents in coastal and offshore purse seine fisheries

Hypothesis		Significance	Result
H_1	There is a significant correlation between the type of industrial accident and the fishing area	0.106	Rejected
H_2	There is a significant correlation between the type of industrial accident and the age of fishing vessel	0.057	Rejected
H_3	There is a significant correlation between the type of industrial accident and the gross tonnage	< 0.001	Accepted
H_4	There is a significant correlation between the type of industrial accident and the month	0.615	Rejected
H_5	There is a significant correlation between the type of industrial accident and the time of occurrence	0.023	Accepted
H_6	There is a significant correlation between the type of industrial accident and the age	0.102	Rejected
H_7	There is a significant correlation between the type of industrial accident and the nationality	0.003	Accepted
H_8	There is a significant correlation between the type of industrial accident and the onboard position	0.018	Accepted
H_9	There is a significant correlation between the type of industrial accident and the work process	< 0.001	Accepted
H_{10}	There is a significant correlation between the type of industrial accident and the environmental causes	< 0.001	Accepted

Table 6. Chi-square test on types of industrial accidents in coastal and offshore purse seine fisheries

Hypothesis		Purse seine	Significance	Result
H_3	There is a significant correlation between the type of industrial accident and the gross tonnage	Coastal	0.245	Rejected
		Small	0.121	Rejected
		Main boat	0.629	Rejected
		Light boat	0.595	Rejected
		Carrier	0.611	Rejected
H_5	There is a significant correlation between the type of industrial accident and the time of occurrence	Coastal	0.017	Accepted
		Small	0.125	Rejected
		Main boat	1.000	Rejected
		Light boat	0.859	Rejected
		Carrier	1.000	Rejected
H_7	There is a significant correlation between the type of industrial accident and the nationality	Coastal	0.289	Rejected
		Small	0.196	Rejected
		Main boat	0.378	Rejected
		Light boat	0.049	Accepted
		Carrier	0.064	Rejected
H_8	There is a significant correlation between the type of industrial accident and the onboard position	Coastal	0.380	Rejected
		Small	0.125	Rejected
		Main boat	0.458	Rejected
		Light boat	0.623	Rejected
		Carrier	0.276	Rejected
H_9	There is a significant correlation between the type of industrial accident and the work process	Coastal	0.002	Accepted
		Small	0.107	Rejected
		Main boat	< 0.001	Accepted
		Light boat	0.011	Accepted
		Carrier	< 0.001	Accepted
H_{10}	There is a significant correlation between the type of industrial accident and the environmental causes	Coastal	< 0.001	Accepted
		Small	< 0.001	Accepted
		Main boat	< 0.001	Accepted
		Light boat	< 0.001	Accepted
		Carrier	< 0.001	Accepted

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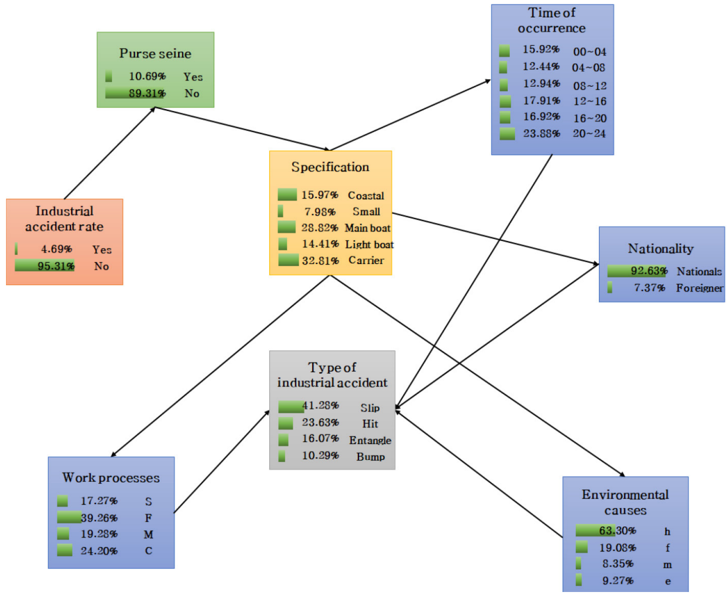

Fig. 1. Bayesian network for quantitative analysis of industrial accidents type in coastal and offshore purse seine fisheries.

fishing industry.

The third node represents the classification within purse seine fisheries (coastal, small-scale, and large-scale) and shows the probability of accidents in each category. When the second node connects to the third node, it acts as the parent of the third node while remaining the child of the root node. This sequence, from root node to third node, enables inference of posterior probabilities of accidents in coastal, small-scale, and large-scale purse seine fisheries when an industrial accident occurs in the coastal and offshore fishing industry.

Following the Bayesian network structure, the network extended to the final node, enabling inference of risk factors for each accident type. This structure facilitates quantitative risk assessment for each accident type based on influential risk factor within purse seine fisheries.

Bayesian network analysis results for costal purse seine fisheries

Table 7 presents quantitative risk of industrial accidents based on time of occurrence, work processes, and environmental causes in coastal purse seine fisheries. The corresponding quantitative risks associated with each variable within these three factors were as follows:

In coastal purse seine fisheries, accident risk varied by time of occurrence. Slip risks peaked from 12 to 4 PM , hits and bumps were the highest from 8 to 12 AM, and entrapment risks peaked from 8 to 12 PM. Overall, the four major accident types had the highest risk from 8 PM to 12 AM, with this period exhibiting a 2.57 times greater risk than the lowest-risk period, from 12 to 4 AM.

In terms of work processes, quantitative risk analysis for industrial accidents showed that the highest risks in all accident types occurred during fishing operations. The risk associated with fishing was approximately 2.81 times higher than that of sailing, which was the next highest-risk activity, indicating that most industrial accident risks were concentrated in fishing process.

The quantitative risk of industrial accidents varied with environmental cause and accident type. Slips and bumps had a high risk associated with the hull, whereas hits and entrapments were more likely to be caused by fishing gear. The risk of hull causing slips was significantly higher than risk of other causes. Additionally, the hull posed the most risk among the four major types of industrial accidents, being 2.1 times higher risk than fishing gear and approximately 7.45 times higher risk than machinery and external causes.

Quantitative risk analysis based on fishery and vessel types

Work processes were the only significant factor associated with accident types in small-scale offshore purse seine fisheries. Table 8 shows the quantitative risk of each accident type based on

Table 7. Quantitative risk of types of industrial accidents in coastal purse seine fisheries

	Slip	Hit	Entangle	Bump	Total
Time of occurrence					
00–04	0.00003	0.000018	0.000023	0.00001	0.000081
04–08	0.000051	0.000012	0.000017	0.0000073	0.0000873
08–12	0.000074	0.000013	0.00005	0.000011	0.000148
12–16	0.00012	0.0000085	0.000014	0.000022	0.0001645
16–20	0.000052	0.0000094	0.00003	0.000017	0.0001084
20–24	0.000087	0.00004	0.000046	0.000035	0.000208
Work process					
S	0.000084	0.000026	0.000027	0.000026	0.000163
F	0.00026	0.000041	0.00012	0.000037	0.000458
M	0.000046	0.000022	0.000023	0.00002	0.000111
C	0.000027	0.000011	0.00001	0.00002	0.000068
Environmental cause					
h	0.00033	0.000023	0.000055	0.000054	0.000462
f	0.000056	0.000048	0.000092	0.000024	0.00022
m	0.000014	0.000017	0.000017	0.000014	0.000062
e	0.000023	0.000011	0.000016	0.000012	0.000062

Table 8. Quantitative risk of types of industrial accidents in small purse seine fishery

Environmental cause	Slip	Hit	Entangle	Bump	Total
h	0.00015	0.000029	0.0000096	0.000034	0.0002226
f	0.000025	0.000036	0.000071	0.00002	0.000152
m	0	0	0	0	0
e	0.0000053	0.0000053	0	0.000011	0.0000216

the work process in this category.

The quantitative risk caused by environmental factors in small-scale offshore purse seine fisheries was similar to that in coastal purse seine fisheries. Hull-related slips and bumps were linked to the hull, whereas hits and entrapments were associated with fishing gear. The hull posed the highest risk among all the four major accident types and the risk level was more than 10 times higher than that posed by external causes. Notably, no major industrial accidents related to machinery were recorded in small-scale offshore purse seine fisheries throughout the 5-year period (2018–2022), indicating a calculated risk of zero. Additionally, no entrapment accidents caused by external causes were reported.

In large-scale offshore purse seine fisheries, which include the main boat, light boats, and carriers, work processes and accident causes were associated with accident types on the main boat and carriers. On light boats, accident types were influenced by work processes, accident causes, and fishermen nationality. Tables 9, 10, and 11 present the quantitative risk for each accident type on the main boat, light boats, and carriers, respectively, in large-scale offshore purse seine fisheries.

The risk analysis of accident types according to the work process on the main boat revealed that slips occurred most frequently during sailing, whereas hits, entrapments, and bumps all showed high risk levels during fishing operations. Among the four working processes, fishing showed the highest risk, which was 2.71, 5.76, and 19.24 times greater than maintenance, sailing, and catch unloading, respectively. The results of risk analysis of environmental causes were similar to those of coastal and small-scale offshore purse seine fisheries: slips and bumps were associated with the hull and hits and entrapments were associated with fishing gear. Consistent with other categories, the hull posed the highest risk across the four major accident types.

The risk analysis of industrial accidents on light boats by fishermen nationality revealed that Korean nationals faced approximately 35 times higher risk than foreigners. Of the 213 industrial accidents recorded on light boats throughout the 5 years, 207 involved nationals, and only 6 involved foreigners. In the risk analysis of industrial accidents on light boats in a large-

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Table 9. Quantitative risk analysis of types of industrial accidents on main boat of large purse seine fishery

	Slip	Hit	Entangle	Bump	Total
Work process					
S	0.0001	0.000041	0.000036	0.00003	0.000207
F	0.00043	0.00045	0.00023	0.000083	0.001193
M	0.00027	0.00011	0.000025	0.000036	0.000441
C	0.000021	0.00002	0.000007	0.000014	0.000062
Environmental cause					
h	0.00046	0.00014	0.0001	0.000088	0.000788
f	0.00014	0.00029	0.00016	0.000036	0.000626
m	0.0000083	0.00017	0.000017	0.000014	0.0002093
e	0.00021	0.000025	0.000017	0.000025	0.000277

Table 10. Quantitative risk analysis of types of industrial accidents on light boat of large purse seine fishery

	Slip	Hit	Entangle	Bump	Total
Nationality					
Nationals	0.00053	0.00019	0.00012	0.000079	0.000919
Foreigners	0.000011	0.0000056	0.0000031	0.0000068	0.0000265
Work processes					
S	0.0002	0.000054	0.000044	0.000028	0.000326
F	0.00019	0.00011	0.000065	0.000031	0.000396
M	0.00014	0.000027	0.0000099	0.000019	0.0001959
C	0.000015	0.000012	0.0000024	0.0000078	0.0000372
Environmental causes					
h	0.00039	0.00012	0.000082	0.000059	0.000651
f	0.000024	0.000039	0.000022	0.00001	0.000095
m	0.000005	0.000033	0.0000072	0.0000064	0.0000516
e	0.00012	0.000011	0.0000093	0.00001	0.0001503

Table 11. Quantitative risk analysis of types of industrial accidents on carrier of large purse seine fishery

	Slip	Hit	Entangle	Bump	Total
Work processes					
S	0.00019	0.000061	0.000046	0.000032	0.000329
F	0.0001	0.000062	0.000033	0.000021	0.000216
M	0.00026	0.000053	0.000024	0.000051	0.000388
C	0.00045	0.00045	0.000083	0.00025	0.001233
Environmental causes					
h	0.0009	0.00045	0.00015	0.00028	0.00178
f	0.000024	0.000027	0.000019	0.000016	0.000086
m	0.0000095	0.00014	0.000016	0.000038	0.0002035
e	0.000073	0.000009	0.0000041	0.000017	0.0001031

scale purse seine fishery fleet, the slip risk among nationals was calculated to be 48.18 times higher than that among foreigners (0.00053 vs. 0.000011), indicating the largest observed disparity across all analysis variables. Similar to the findings on the main boat, the risk of slips was the highest during sailing, whereas hits, entrapments, and bumps posed the greatest risk during fishing operations. Risk analysis of the work process showed that fishing posed the highest risk, which was 1.21, 2.02, and 10.65 times greater than risks for sailing, maintenance, and catch unloading, respectively. Unlike in other purse seine fishery categories, risk analysis of the work process on the main boat revealed that fishing posed the highest risk in large-scale offshore purse seine fisheries, with maintenance (0.000441) carrying a higher risk than sailing (0.000207). Although fishing had the highest overall risk, it was only 1.21 times higher than sailing, indicating that sailing had a comparatively high risk level. The risk of environmental causes on light boats differed from that on other vessel categories, with the hull presenting the highest risk across all the accident types. The overall risk associated with hull was 6.85, 12.62, and 4.33 times higher than that associated with fishing gear, machinery, and external causes, respectively.

In large-scale offshore purse seine fisheries, carriers are mostly used to transport the catch. The analysis of accident risks by work process on carriers reflects this role because all accident types posed the highest risk during the catch-unloading process. Risks during catch unloading were 3.75, 5.71, and 3.18 times higher than those associated with sailing, fishing, and maintenance, respectively. Among these, the risks of slips (0.00045), hits (0.00045), and bumps (0.00025) were significantly higher during catch unloading than during other work processes. The risks of slips, hits, and bumps during catch unloading were particularly high compared to those during other processes. As with light boats, environmental cause analysis indicated that hull posed the highest risk, at 20.70, 8.75, and 17.26 times higher than those associated with fishing gear, machinery, and external causes, respectively, confirming that a significant portion of the risk is concentrated on the hull. Notably, risks associated with the hull were more than 20 times higher than those associated with fishing gear.

Conclusion

A quantitative risk analysis was conducted on 1,478 approved industrial accident insurance claims over a 5-year period (2018–2022) in purse seine fisheries, which are classified as high-risk within coastal and offshore fisheries. Separate statistical analyses were conducted on these insurance claim approvals across different types of purse seine fisheries, which were categorized into coastal, small-scale offshore, and large-scale offshore. Large-scale offshore purse seine fisheries, which operate as fleets, were subdivided into main boats, light boats, and carriers to assess the distinctive characteristics of industrial accidents according to vessel type within a fleet. Chi-square tests were conducted to determine associations between accident types and each fishery category or vessel type.

The chi-square test results indicated that accident types were significantly associated with time of occurrence, work processes, and environmental causes in coastal purse seine fisheries. In small-scale offshore purse seine fisheries, only environmental causes showed a significant association with accident types. Within large-scale offshore purse seine fisheries, accident types on main boats and carriers were significantly associated with work processes and environmental causes; however, on light boats, accident types were associated with fishermen nationality, work processes, and environmental causes.

A Bayesian network was constructed using the factors with significant associations with different fishery categories and vessel types to quantitatively evaluate the risk of the four major accident types across each fishery category and vessel type. In coastal purse seine fisheries, the highest risk associated with the time of occurrence was between 8 and 12 PM. Based on accident type, slips caused the highest risk from 12 AM to 4 PM, hits and bumps from 8 to 12 PM, and entrapments from 8 to 12 AM. For work processes, fishing presented the highest risk across all the accident types, with the risks being 2.81, 4.13, and 6.74 times greater than those of sailing, maintenance, and catch unloading, respectively. Environmental cause analysis showed that hull-related accidents posed the greatest risk, and the risk levels were 2.1 times higher than fishing gear and 7.45 times higher than machinery and external causes, respectively.

It should be noted that limited data were available for risk analysis in small-scale purse seine fisheries, and environmental causes were the only factor that showed a significant association with accident types. Among the environmental causes, hull-related slips/bumps and fishing gear-related hits/entrapments were the most frequent accidents. No major accidents associated with machinery were recorded over the 5-year period, indicating a calculated risk of zero.

This study contributes substantially to the advancement of safer and more sustainable purse seine fisheries by quantitatively assessing the risk of industrial accidents involving fishermen across different purse seine fishing categories and vessel types.

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No potential conflict of interest relevant to this article was reported.

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References

Burns RB, Dobson CB. Chi-square. In: Burns RB, Dobson CB, editors. Experimental psychology: research methods and statistics. Dordrecht: Springer; 1981. p. 223-42.

Güngör M, Bulut Y. On the chi-square test. Doğu Anadolu Bölgesi Araştırmaları. 2008;7:84-9.

Hänninen M, Kujala P. Bayesian network modeling of port state control inspection findings and ship accident involvement. Expert Syst Appl. 2014;41:1632-46.

Hänninen M, Mazaheri A, Kujala P, Montewka J, Laaksonen P, Salmiovirta M, et al. Expert elicitation of a navigation service implementation effects on ship groundings and collisions in the Gulf of Finland. Proc Inst Mech Eng O J Risk Reliab. 2013;228:19-28.

International Maritime Organization (IMO). Revised guidelines for formal safety assessment (FSA) for use in the IMO rule-making process. London: IMO; 2018. Report No.: MSC-MEPC.2/Circ 12/Rev.

Jaremin B, Kotulak E. Mortality in the Polish small-scale fishing industry. Occup Med. 2004;54:258-60.

Jin D. The determinants of fishing vessel accident severity. Accid Anal Prev. 2014;66:1-7.

Jin D, Thunberg E. An analysis of fishing vessel accidents in fishing areas off the northeastern United States. Saf Sci. 2005;43:523-40.

Kitson NK, Constantinou AC, Guo Z, Liu Y, Chobtham K. A survey of Bayesian network structure learning. Artif Intell Rev. 2023;56:8721-814.

Korean Law Information Center (KLIC). Fisheries act [Internet]. 2024 [cited 2024 May 1]. https://www.law.go.kr/lsInfoP.do?lsiSeq=255835&efYd=20240501#0000

Laursen LH, Hansen HL, Jensen OC. Fatal occupational accidents in Danish fishing vessels 1989-2005. Int J Inj Control Saf Promot. 2008;15:109-17.

Lazakis I, Kurt RE, Turan O. Contribution of human factors to fishing vessel accidents and near misses in the UK. J Shipp Ocean Eng. 2014;4:245-61.

McHugh ML. The Chi-square test of independence. Biochem Med. 2013;23:143-9.

Ministry of Employment and Labor (MOEL). Status of occupational accident in 2022. Sejong: MOEL; 2023. p. 1-648.

National Institute of Fisheries Science (NIFS). Illustrations of Korean fishing vessels. Busan: NIFS; 2018. p. 1-107.

Obeng F, Domeh V, Khan F, Bose N, Sanli E. Capsizing accident scenario model for small fishing trawler. Saf Sci. 2022;145:105500.

Pearl J. Bayesian inference. In: Pearl J, editor. Probabilistic reasoning in intelligent systems: networks of plausible inference. San Francisco, CA: Morgan Kaufmann; 1988. p. 29-75.

Sirkin MR. The Chi-square test. In: Sirkin MR, editor. Statistics for the social sciences. 3rd ed. Thousand Oaks, CA: SAGE; 2006. p. 397-442.

Trucco P, Cagno E, Ruggeri F, Grande O. A Bayesian belief network modelling of organisational factors in risk analysis: a case study in maritime transportation. Reliab Eng Syst Saf. 2008;93:845-56.

Wang F, Du W, Feng H, Ye Y, Grifoll M, Liu G, et al. Identification of risk influential factors for fishing vessel accidents using claims data from Fishery Mutual Insurance Association. Sustainability. 2023;15:13427.

Weber P, Medina-Oliva G, Simon C, Iung B. Overview on Bayesian networks applications for dependability, risk analysis and maintenance areas. Eng Appl Artif Intell. 2012;25:671-82.

Zhang G, Thai VV. Expert elicitation and Bayesian network modeling for shipping accidents: a literature review. Saf Sci. 2016;87:53-62.

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