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Accessing Occupational Health Risks Posed by Fishermen Based on Fuzzy AHP and IPA Methods: Management and Performance Perspectives

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Abstract: In developing countries such as China, commercial fishermen's occupational health risks are rarely studied despite being extremely critical for the sustainable development of the fisheries sector. In this study, we attempt for the first time to categorize and prioritize multiple types of health risks posed by these fishermen. This was accomplished by conducting a structured questionnaire survey between 9 January 2022 and 24 May 2022. We sought the professional opinion of fishermen that were located in the coastal areas of Zhejiang, China, namely Zhoushan (121 responses, 64%), Taizhou (66 responses, 49%), and Wenzhou (94 responses, 53%). This study used two hundred eighty-one questionnaires with a consistency ratio (CR) below 0.1 and completed in every respect. Fuzzy Analytical Hierarchical Process (Fuzzy AHP) and Importance Performance Analysis (IPA) statistics were employed to perform statistical analysis. Results have revealed that commercial fishermen's health is affected by five main risk factors, namely natural (0.058), biological (0.088), social (0.152), psychological (0.234), and physical (0.468), which are arranged from the least to the most significant risk factors. As for the performance of the main risk factors, the physical risk was ranked first (4.786), followed by social risk (4.571), psychological risk (4.214), biological risk (4.000), and natural risk (3.429). These research findings can serve as guidelines for managers. Moreover, this study discusses ramifications, constraints, and proposals for future research.

Keywords: MCDA; occupational health; risk assessment; sustainability; IPA; AHP

Citation: Yan, J.-L.; Xue, Y.-J.; Mohsin, M. Accessing Occupational Health Risks Posed by Fishermen Based on Fuzzy AHP and IPA Methods: Management and Performance Perspectives. *Sustainability* **2022**, *14*, 13100. https://doi.org/10.3390/su142013100

Academic Editors: Vinod Kumar and Raj Setia

Received: 12 August 2022
Accepted: 10 October 2022
Published: 13 October 2022

1. Introduction

Fishing is considered the riskiest occupation in the world, supporting more than half a billion people [1–3]. However, it is also one of the most difficult sectors to understand the challenges faced by workers who perform these traditional jobs. Contrary to most industrial workers, they often work in less formal environments with unconventional work schedules or those that last for very long periods [4]. Physical stress and risky conditions are frequent in industrial fishing. It is common for fishermen to have musculoskeletal disorders due to the overuse of their loco-motor system [5]. Therefore, fishermen tend to have the highest injury and mortality rates [6]. According to statistics, 80 of every 100,000 fisheries employee die yearly. It happens due to economic, cultural, and social risk factors [7]. Unfortunately, it is primarily the low-income members of the community who are the most harmed by mishaps at sea.

In terms of wild and farmed fish, China leads global production. As of 2016, Chinese fishermen made up 25% of the world's fishermen population. Fishery production represented 142% of gross domestic product with revenue of 1281 billion Renminbi [8]. Compared to other sectors, the fishery sector faces a multitude of risks exacerbated by natural catastrophes [9]. In China, fisheries are considered one of the highest-risk occupations compared to others when it comes to accident figures [10]. The death rate among fishermen globally was reported to be the highest as of 2005 [11]. There were approximately 120 deaths and 832 injuries per year between 1994 and 2011 among 100,000 fishermen [8]. The actual losses can be greater than these reported figures. Losses in economic activity, environmental damage, and personal injuries are common hazards associated with the fishing industry. On the Chinese coastline, several meteorological disasters occur each year due to various natural phenomena affecting fisheries and aquaculture. Likely, adverse weather conditions will severely impact fisheries. Fishermen in China have a considerable number of vessels that are small or medium in size. There are too many risks associated with the work of fishermen for their limited financial resources to handle. Therefore, Chinese fishermen face challenges in dealing with fishery risks, which pose serious concerns [8].

For risk evaluation, data can be examined with various analytical methods. The data analysis techniques and approaches are customized to the study's validity, scope, and objective. Assessing as well as prioritizing risks using multi-criterion algorithms, viz., Multi-Criteria Decision Analysis (MCDA), is the most robust and accurate approach to do so. Fisheries risk management using MCDA is very popular [12]. There are several MCDA techniques currently being used, such as Vise Kriterijumska Optimizacija Kompromisno Resenje (VIKOR), aggregation operators, Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Analytic Network Process (ANP), Analytical Hierarchy Process (AHP), and Importance Performance Analysis (IPA) [13,14]. A complicated method is problematic when managing people facing urgent situations and making quick judgments.

Other than SAW, AHP, and IPA, all of the aforementioned techniques are complex and difficult to implement. For this study, we selected AHP and IPA routines among these three statistical techniques. These two methods were selected based on their relevance and suitability to our research objectives. Although AHP is an excellent tool for categorizing and prioritizing risk factors, it lacks the ability to suggest improvements to performance management. The IPA algorithm, on the other hand, is a specialized statistical procedure for determining the most suitable performance management options. This study aimed to rank, prioritize, and find performance management options to improve occupational health risks among fishermen. Therefore, the first step of this process was to utilize AHP, and the second or final step was to use IPA analysis to improve management. It was therefore imperative to use both methods to achieve the desired results. Additionally, previous published studies have also demonstrated the integration of AHP and IPA [15,16], since IPA has only range and does not have average values. Hence, in this condition we have highlighted data distribution in Table 1 and have provided all of the data acquisition questionnaires which will facilitate future research in this field.

In 1977, Saaty introduced the AHP routine and refined it further over the subsequent years [17–19]. Using this method, decision-makers can quickly determine which option would be most effective out of many that could be considered. Moreover, it can also assess performance continuity [20]. The pairwise assessment approach enables decision-makers to arrive at a trustworthy risk control solution based upon weights and rational scores. AHP has been applied in published research works for a variety of factors. This technique is able to provide intuitive appeal, determine data ambiguities, and be flexible when it comes to operations. Furthermore, it proposes a hierarchical approach, which also helps diminish selection errors. Moreover, it allows a rational evaluation of two objects. In addition, this technique is better suited for judging uncertain risks [21,22]. Due to the benefits outlined above, AHP and IPA procedures were applied in this study.

The health of fishermen has been documented as being exceptionally poor due to various risks. In contrast, little research has been carried out on occupational health risks faced by fishermen, particularly in low-income nations [23]. As cited above, several studies have attempted to address the risks faced by Chinese fishermen. However, there is a lack of comparison between risks in these studies which prevents them from adequately managing them. In this study, this gap is being filled for the first time. Thus, the present study intends to enhance the occupational health of Chinese fishermen in the following ways:

(1) Identify risks faced by Chinese fishermen; (2) determine their priority for management; and (3) evaluate how these risks can be managed. To achieve these three objectives, we need to answer the following questions:

(1) Do Chinese fishermen face a wide variety of occupational health risks?
(2) What is the correct order in which the main and sub-risk factors should be ranked for their management?
(3) How can we improve the performance management of these risks?

Table 1. Socio-demographic profile of survey respondents.

Characteristics		Number	%
Marital status	Single	82	29.2
	Married	199	70.8
Education	Primary school	65	23.2
	Secondary school or above	216	76.8
Region	Zhoushan	121	43.0
	Taizhou	66	23.4
	Wenzhou	94	33.6
Duration of work	15 years or more	174	61.9
	Less than 15 years	107	38.1
Working duration/year	6 months or more	179	63.7
	Less than 6 months	102	36.3
Working hours/day	10 h or more	206	73.3
	Less than 10 h	75	26.7
Place of fishing	Inshore	86	30.6
	Offshore	195	69.4
Type of fishing	Long line, trap or hand line	111	39.6
	Gillnet	170	60.4
	Total	281	100.0

The research scope involves finding, rating, and ordering risks faced by Chinese fishermen. In addition, it describes different ways to combat occupational hazards. Since this study's core objective was to increase fishermen's occupational health which was a non-financial objective. That is why we have used non-financial intangible risk factors. MCDA, using intangible risk factors, has been extensively discussed in the literature [24–26]. Therefore, we have evaluated fishermen's occupational health based on these risk factors.

2. Review of Literature

Observations from the literature indicate that fishermen are vulnerable to physical, psychological, social, biological, and natural risks. These risks are discussed briefly in the following section.

2.1. Social Risks

The lack of social protection, such as insurance, makes fishermen particularly vulnerable to social risks [27]. Fishermen are rarely covered by their health insurance, and morbidity and mortality rates remain alarming in the fishing industry [28]. Remote working environments, financial hardship, and mental strain can negatively affect worker safety [29]. Fishermen suffer from physical ailments most frequently due to poverty. The lack of education facilities is responsible for these problems. Fishermen's health is very much affected by what they live through daily. Poor quality of the water badly affects fishermen's health, making them more susceptible to diseases. The health of fishermen is adversely affected by food insecurity, both during and outside the fishing season [30,31]. Relocation is a serious problem in China, and if not handled well, it could worsen [32]. A lack of insurance worldwide significantly hinders the sustainable development of the fishing industry.

2.2. Physical Risks

Fishermen frequently suffer from health problems as a result of stressful working conditions and strenuous work [27]. The use of heavy equipment and excessive working hours result in serious health hazards for the fishermen [23]. Falling, slipping, or tripping while working as a fisherman often results in injury [33]. Equipment that makes noise contributes to adverse health effects, such as hearing loss. The ship's engine rooms have an average noise level of around 113 dB, which is high enough to cause hearing impairments. Moreover, Fishermen tend to sustain physical injuries by slipping off ships' decks. Injuries also occur while operating fishing equipment [5]. In addition to vision loss, overweight, heart disease, and injuries to the skin, the circumstances in which they work can also lead to hearing impairment. Compared to the general population, they have an increased likelihood of all these ailments [34,35].

Hazards that may adversely affect worker safety include fatigue, remote workplaces, inclement weather, financial hardship, equipment failures, mental strain, rough seas, and vigorous exercise. Fishermen may more likely suffer health complications due to all these factors [36,37]. In addition to performing intense work, fishermen frequently handle catches manually (pulling, lifting, and pushing), resulting in excessive strain on their musculoskeletal structures [38]. The literature suggests that heavy manual handling, lifting, hand-held lifting, and traction and push are risk factors endured by fishermen [39]. On fishing vessels, the decks are crowded and constantly in motion, making it possible to sustain injuries [40]. Fishermen are particularly susceptible to hyperkeratosis. In areas of high pressure and repeated contact, dead cells accumulate. It is called a callus. Corns, however, develop in areas of irritation [41].

2.3. Natural Risks

Fishermen's health is negatively affected by harsh environmental conditions [23]. Fishermen are more likely to get skin burns because of sun radiation [5]. Inclement weather and equipment failure adversely affect fishermen's safety [42]. Health hazards such as adverse environmental factors are new contributors to health problems. These influences stem from exposure to variations in climate features, including humidity and temperature fluctuations. In the sea, sun exposure is more likely to cause skin and eye damage than on land since sunlight is reflected unobstructed [43]. Temperature changes also negatively affect the health of fishermen [44]. It has been found that fluctuations in the ambient environment are associated with heart disease and death [45]. Fishermen are very prone to sunburn [46]. Most often, exposure to sunlight leads to premalignant and malignant lip lesions in fishermen. Additionally, the lower lip has a vermilion margin [47].

2.4. Psychological Risks

It takes a lot of energy and time to work as a fisherman. Many of the time, their workplace conditions are harsh. During long voyages at sea, fishermen need to maintain an open-air environment while on the boat, as well as interact with the rest of the crew. It further complicates their work. Long work hours and sleep-deprived isolated locations could also pose risks to the safety of fishermen. Aside from that, their work can be difficult to balance with a typical private routine due to high demands. These conditions may exacerbate psychological ailments in fishing industry workers [48]. Fishermen's health is severely impacted by the high demands of the job [5]. They are also affected by crew size, fishery policies, and weather that do not affect many industrial workers [4]. Risky workplace settings and multiple hazards contribute to increasing global fatalities [49].

As fishermen work in the open air on the boat during long sea voyages, their working environment is not comfortable [5]. Sleep deprivation, physical exertion, and hours of strenuous work are common among fishermen as they devote a considerable amount of time away from home [42].

2.5. Biological Risks

Prolonged or frequent exposure to the marine environment and tools used in fisheries may result in contact dermatitis, traumatic injuries, and a portal for introducing infectious agents [50]. It is prevalent for minor cuts and bruises to be ignored at work. Infectious agents such as bacteria enter the body through these cuts and cause inflammation and pus to form. It has been found that fungal infections are more common among fishermen than bacterial infections. A significant source of fungal infections among fishermen is sweating [41]. Fishermen commonly encounter three types of fungal infections: desquamation of the hands, folliculitis, and diaper rash. Warm temperatures and wet conditions, combined with constant dampness and profuse perspiration, exacerbate fungal infection [50]. Biological risk factors, such as viruses, also threaten the health of fishermen. The most common viral infections fishermen encounter are herpetic buttons and skin warts. There are, however, very few cases of parasitic diseases, including scabies [41].

3. Materials and Methods

The materials and methods used to carry out this study are described in this section.

3.1. Research Outline

In developing countries such as China, fishermen's occupational health risks are rarely studied. Hence, the present study investigated, categorized, and evaluated these risks. The conceptual background of this study is illustrated in Figure 1. We conducted this study using a meticulous process. The first step was to review the literature to determine Chinese fishermen's occupational health risks. Furthermore, a plan for responding to these risks was outlined. We categorized risks composed of main and sub-risk factors based on the gathered information. The second step involved analyzing these data to identify risks in order of importance for their management. Lastly, an IPA was conducted to determine operational optimization strategies based on risk importance and performance.

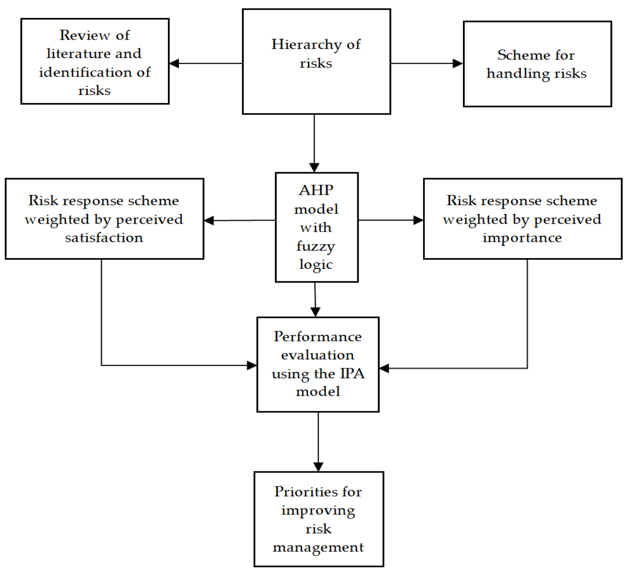

Figure 1. Conceptual background of this study.

In light of recent empirical research on risk control, a bi-layered hierarchy was constructed. In the first layer, there were five main risk factors, whereas in the second, there were 24 risk sub-factors (Figure 2). A fuzzy AHP was then used to rank the risks. Moreover, to improve risk management, the IPA routine was used to prioritize risk factors.

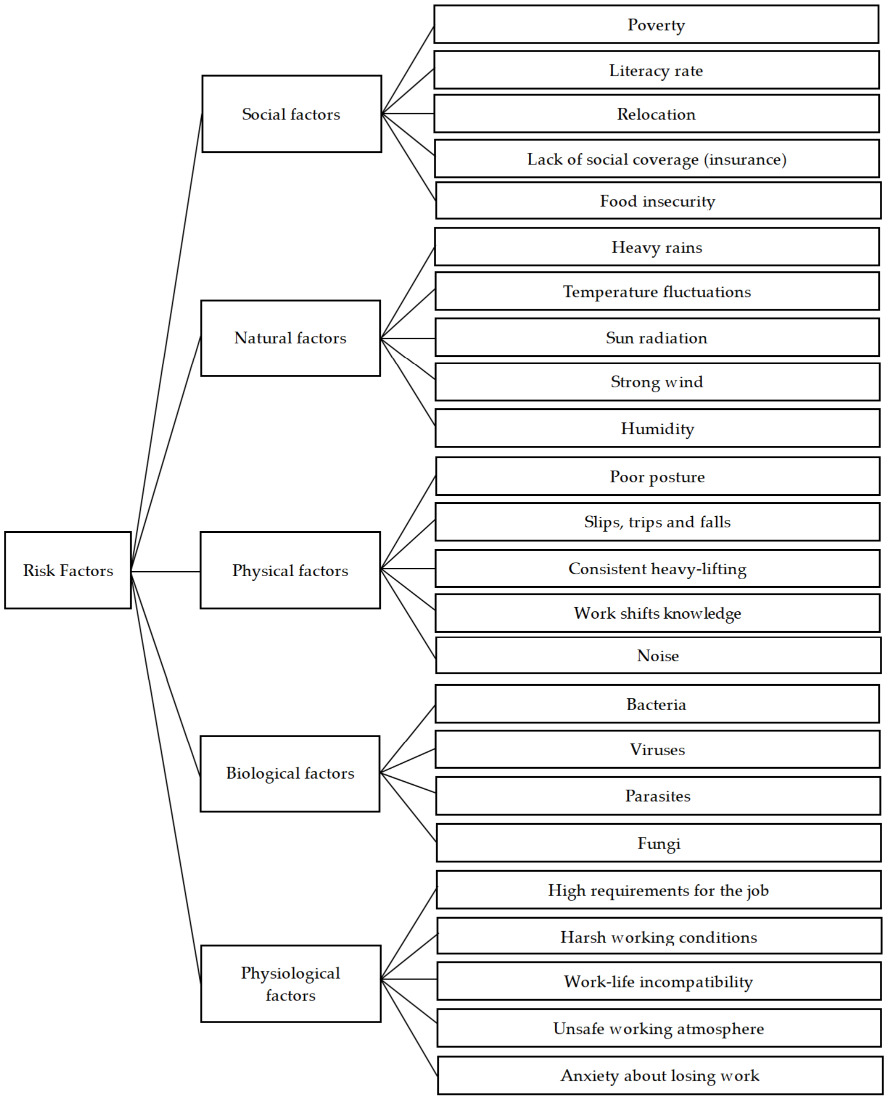

Figure 2. Hierarchy (bi-layered) of risk factors.

3.2. Data Acquisition

The fuzzy AHP and IPA questionnaires were developed using published research based on nine-point scales [14]. Later on, an accuracy review was conducted by a research team of three professors. Afterward, a second review by two marine fisheries experts checked the clarity and understanding of the statements. For data collection, we conducted a formal questionnaire through emails and in-person discussions between 9 January 2022 and 24 May 2022. For the survey, we contacted fishers located in the coastal areas of Zhejiang, China, namely Zhoushan (121 responses, 64%), Taizhou (66 responses, 49%), and Wenzhou (94 responses, 53%). Table 1 presents a socio-demographic profile of survey respondents. We collected and analyzed 281 valid questionnaires with a consistency ratio below 0.1 (see Supplementary Materials for sample questionnaires used to conduct this study).

3.3. Data Analysis

The response rate of the survey participants varied by region. The statistical methods, viz., fuzzy AHP, and IPA used in this study, were applied to data by downloading the Expert Choice 2000 (2nd Edition) program created by Expert Choice (Arlington, VA, USA).

3.3.1. Fuzzy AHP

A fuzzy AHP allows us to objectively determine and apply criteria for making decisions. This technique compares criteria and their respective alternatives and can also be applied to situations involving many options [51]. Using fuzzy logic, weights, as well as performances, are measured. The ranking of individual preferences is impossible to determine. People's decisions are ambiguous due to the inconclusiveness and uncertainty of experts' opinions. Based on Pan's [52] proposal, fuzzy logic can be used to solve this problem. Therefore, this study presents a fuzzy AHP as a risk assessment tool. It is possible to come up with unclear conclusions based on fuzzy reasoning. The analysis of fuzzy sets and the assessment of hierarchies are used to create fuzzy AHP [51]. This method translates participants' opinions into a raw number by comparing pairs. Fisheries management is one of the many applications of fuzzy AHP [53,54].

Risk factors across layers were analyzed using this study based on 24 pair-wise comparisons. Research involving the viewpoints of many participants with sensitivity to thresholds usually relies on arithmetical or geometric averages. Numbers having fuzzy properties are analyzed to aggregate the opinions of 24 participants. As a measure of concordance, the geometric mean average is applied [17,55]. Afterwards, we constructed fuzzy correlation matrices, which combined 24 pair-wise comparisons. This was accomplished by describing a triangular fuzzy number. The measured score had a maximal, minimal, and geometric average. As a result, risk factors were estimated using fuzzy AHP based on participants' estimates of consequence or likelihood.

3.3.2. Approximation of Weights

It is mostly arithmetic or geometric mean that is used to estimate risk factor weights. In computing these means, maximum values are used to represent all choices made by survey participants. As an alternative, in this study, we employed fuzzy numbers to represent all choices comprehensively. As a first step, a geometric mean representing the choices of survey participants was calculated [18,55]. Later, we developed fuzzy matrices using the highest and lowest geometric means. We then assigned weights to risk factors based on this matrix.

3.3.3. Fuzzy Matrix (Positive and Reciprocal)

We considered a fuzzy matrix which was positive and reciprocal. This matrix was expressed as follows:

$$\widetilde{A} = [\widetilde{a}_{ij}]_{n\times n}$$

Here, $\widetilde{a}_{ij}$ stood for triangular fuzzy figure which was represented as follows:

$$\widetilde{a}_{ij} = [l_{ij}, m_{ij}, u_{ij}]$$

Furthermore, other variables were represented as follows:

$$[l_{ij}, m_{ij}, u_{ij}] = \begin{cases} [1, 1, 1,], \ if\ i = j; \\ \left[\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}\right], \ if\ i \neq j \end{cases}$$

The risk variables were correlated with each of the participants (kth) to create pair-wise comparisons expressed as $A^{(k)}$. In this notation, k = 1 to 22. It was combined with fuzzy set of reciprocating matrices as follows:

$$\widetilde{A} = [\widetilde{a}_{ij}]_{n\times n}$$

In this equality, triangular fuzzy figure was generalized as follows:

$$\widetilde{a}_{ij} = \left[\min_{1 \ll k \ll 30} \left\{ a_{ij}^{(k)} \right\}, \left(\prod_{k=1}^{30} a_{ij}^{(k)} \right)^{1/30}, \max_{1 \ll k \ll 30} \left\{ a_{ij}^{(k)} \right\} \right]$$

Here, both i and j ranged between 1 and n.

These integers were arithmetically manipulated and represented as follows [56]:

$$\widetilde{a}_{ij} = \begin{cases} [1, 1, 1,], \; if \; i = j; \\ (\widetilde{a}_{ij})^{-1}, \; if \; i \neq j \end{cases}$$

3.3.4. Approximation of Local Weights and Triangular Fuzzy Figure

The geometric average procedure developed by Saaty [17] was used to estimate the local weights of risk variables in $\widetilde{A}$. A specific layout was applied to calculate local weights. Geometric averages for the risk variables (ith; i arranges between 1 and n) were estimated by using mathematical calculations for triangular fuzzy figure represented as follows:

$$\widetilde{w}_i = \left(\prod_{j=1}^{n} \widetilde{a}_{ij} \right)^{1/n} = \left[\left(\prod_{j=1}^{n} l_{ij} \right)^{1/n}, \left(\prod_{j=1}^{n} m_{ij} \right)^{1/n}, \left(\prod_{j=1}^{n} u_{ij} \right)^{1/n} \right], i = 1, 2, \ldots, n$$

Afterwards, we added up the values of $\widetilde{W}_i$. This addition was expressed as follows:

$$\sum_{i=1}^{n} \widetilde{w}_i = \left[\sum_{i=1}^{n} \left(\prod_{j=1}^{n} l_{ij} \right)^{1/n}, \sum_{i=1}^{n} \left(\prod_{j=1}^{n} m_{ij} \right)^{1/n}, \sum_{i=1}^{n} \left(\prod_{j=1}^{n} u_{ij} \right)^{1/n} \right]$$

By using this, risk variables fuzzy weight can be written as follows:

$$\widetilde{W}_i = \frac{\widetilde{w}_i}{\sum_{i=1}^{n} \widetilde{w}_i} = \left[\frac{\left(\prod_{j=1}^{n} l_{ij} \right)^{\frac{1}{n}}}{\sum_{i=1}^{n} \left(\prod_{j=1}^{n} u_{ij} \right)^{\frac{1}{n}}}, \frac{\left(\prod_{j=1}^{n} m_{ij} \right)^{\frac{1}{n}}}{\sum_{i=1}^{n} \left(\prod_{j=1}^{n} m_{ij} \right)^{\frac{1}{n}}}, \frac{\left(\prod_{j=1}^{n} u_{ij} \right)^{\frac{1}{n}}}{\sum_{i=1}^{n} \left(\prod_{j=1}^{n} l_{ij} \right)^{\frac{1}{n}}} \right], \; i = 1, 2, \ldots, n$$

3.3.5. Approximation of Crisp Number

Obtaining crisp numbers was achieved by using the process of defuzziness, i.e., $\widetilde{W}_i$ (i ranges between 1 to n) [57]. This process can be expressed as $W_i = \left(l_i^W + 2m_i^W + u_i^W \right)/4$, $i = 1, 2, \ldots, n$. $\widetilde{W}_i$ values were normalized for all the risk variables to get their corresponding local weights by using $W_i = W_i / \sum_{i=1}^{n} W_i, i = 1, 2, \ldots, n$.

3.3.6. Performance Evaluation

IPA was used to evaluate the performance of the management (Figure 3). Existing management can utilize this method to identify improvements and priorities. Hence, this technique can help organizations identify risks for improvement compared to those requiring substantial resources but not significantly affecting performance. IPA matrix lays out risk importance along the x-axis. On the other hand, it depicts risk performance along the y-axis as a two-dimensional grid divided into four sections or quadrants. There is a high level of importance and performance in Section 1. Hence, it means to keep up the good work to support of greater performance. It is important, but management performance is not well in Section 2. Improvement must be made through prompt attention, thus deeming this section as an area for improvement. In Section 3, attributes should be strategically ranked as low priority, i.e., importance and performance. Moreover, Section 4 qualifies as possible overkill since it consists of attributes with low importance but high performance.

Therefore, other sections other than Section 3 should be wiser at allocating resources to these attributes.

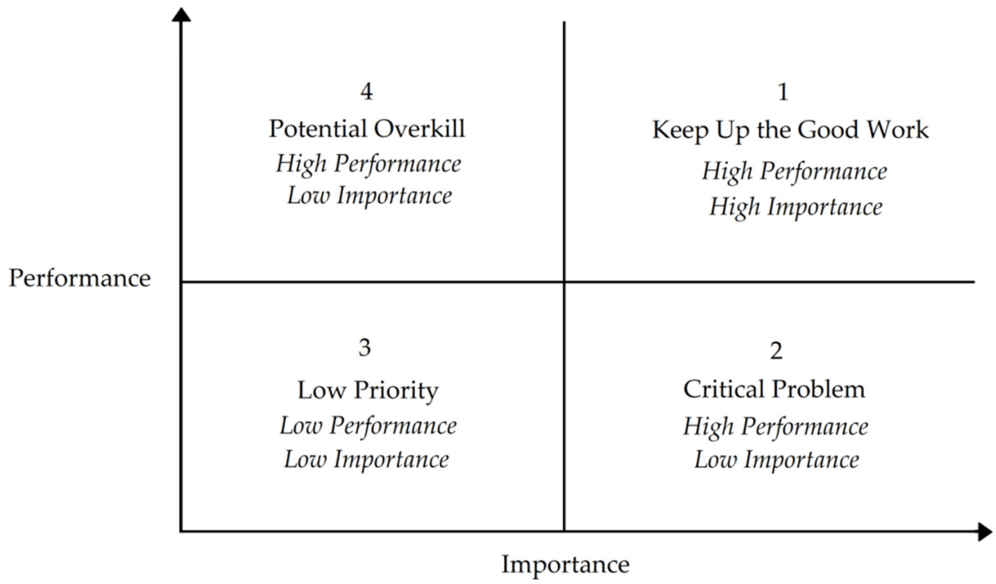

Figure 3. An overview of the IPA.

4. Results

The results of this study are presented in this section.

4.1. Socio-Demographic Profile of Survey Respondents

The survey respondents comprised 82 singles (29.2%) and 199 married people (70.8%). Among them, 65 respondents (23.2%) had only primary school education, while 216 (76.2%) had secondary or above education. Fifty respondents (35.7%) were from Zhoushan, 50 respondents (35.7%) from Taizhou, and 40 respondents (28.6%) from Wenzhou. A total of 174 respondents (61.9%) had been employed for 15 years, while 107 respondents (38.1%) had been employed for less than 15 years. In a year, 179 respondents (63.7%) worked six months or more, while 102 (36.3%) worked less than six months. 86 respondents (30.6%) worked inshore waters, while 195 (69.4%) worked offshore waters. Regarding the type of fishing, 111 respondents (39.6%) used long lines, traps, and hand lines, while 170 respondents (60.4%) used gillnets.

4.2. Rankings of the Main Factors Based on Their Relative Importance (AHP)

The main factors were ranked in the following order based on their relative importance: physical factors (0.468), psychological factors (0.234), social factors (0.152), biological factors (0.088), and natural factors (0.058) (Table 2).

Table 2. Rankings of the main factors based on their relative importance (AHP).

Risk Factors	Importance	Rank
Social	0.152	3
Natural	0.058	5
Physical	0.468	1
Biological	0.088	4
Psychological	0.234	2

4.3. Rankings of the Sub-Factors Based on Their Relative Importance (AHP)

The hierarchy of main risk factors is shown in Figure 4, ranked in order of importance and ranking. The following social sub-factors were ranked in order of importance: poverty (0.486), literacy rate (0.222), food insecurity (0.152), lack of coverage (insurance)

(0.081), and relocation (0.059%). There were five natural sub-factors ranked as follows: sun radiation (0.337), heavy rains (0.289), temperature fluctuations (0.245), strong wind (0.072), and humidity (0.057). The physical sub-factors were ranked according to the following percentages: poor posture (0.430), slips, trips, and falls (0.251), repeated heavy lifting (0.155), shiftwork (0.099), and noise (0.065). Biological sub-factors were ranked in the following order: fungi (0.503), bacteria (0.286), viruses (0.136), and parasites (0.074). The psychological sub-factors included high job demands (0.469), harsh working conditions (0.233), unsafe working environments (0.144), work-life incompatibility (0.090), and anxiety about losing work (0.064).

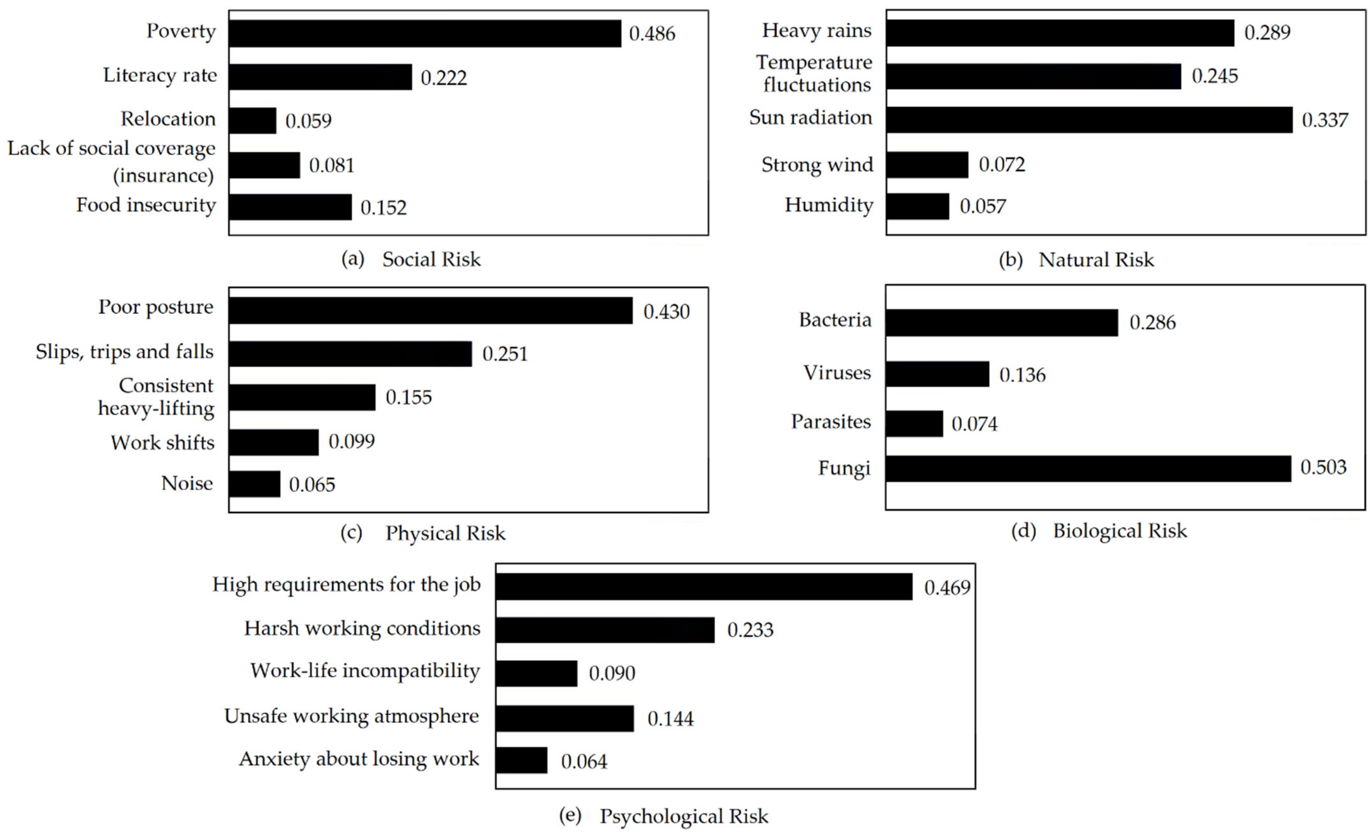

Figure 4. Rankings of the sub-factors based on their relative importance (AHP).

4.4. Rankings of the Main Factors Based on their Performance (IPA)

The main factors were ranked in the following order: physical factors (4.786), social factors (4.571), psychological factors (4.214), biological factors (4.000), and natural factors (3.429) (Table 3).

Table 3. Rankings of the main factors based on their performance (IPA).

Risk Factors	Performance	Rank
Social	4.571	2
Natural	3.429	5
Physical	4.786	1
Biological	4.000	4
Psychological	4.214	3

4.5. Rankings of the Sub-Factors Based on Their Performance (IPA)

There were five social sub-factors ranked from lowest to highest: poverty (4.786), food insecurity (4.643), literacy rate (4.143), relocation (3.929), and lack of social coverage (insurance) (3.857). Among the natural sub-factors, sun radiation (4.571) ranked highest, followed by temperature variations (3.786), strong winds (3.714), heavy rains (3.357), and humidity (3.214). The following physical sub-factors were ranked in order of importance: slips, trips, and falls (4.214), poor posture (3.643), consistent heavy lifting (3.571), work shifts (3.500), and noise (2.929). The biological sub-factors were ranked as follows: fungi (4.357), parasites (3.429), bacteria (3.286), and viruses (3.000). In the order of importance of psychological sub-factors, unsafe working conditions ranked first (4.429), harsh working conditions ranked second (4.286), high job requirements ranked third (3.071), work-life incompatibility ranked fourth, and anxiety about losing work ranked fifth (2.714) (Figure 5).

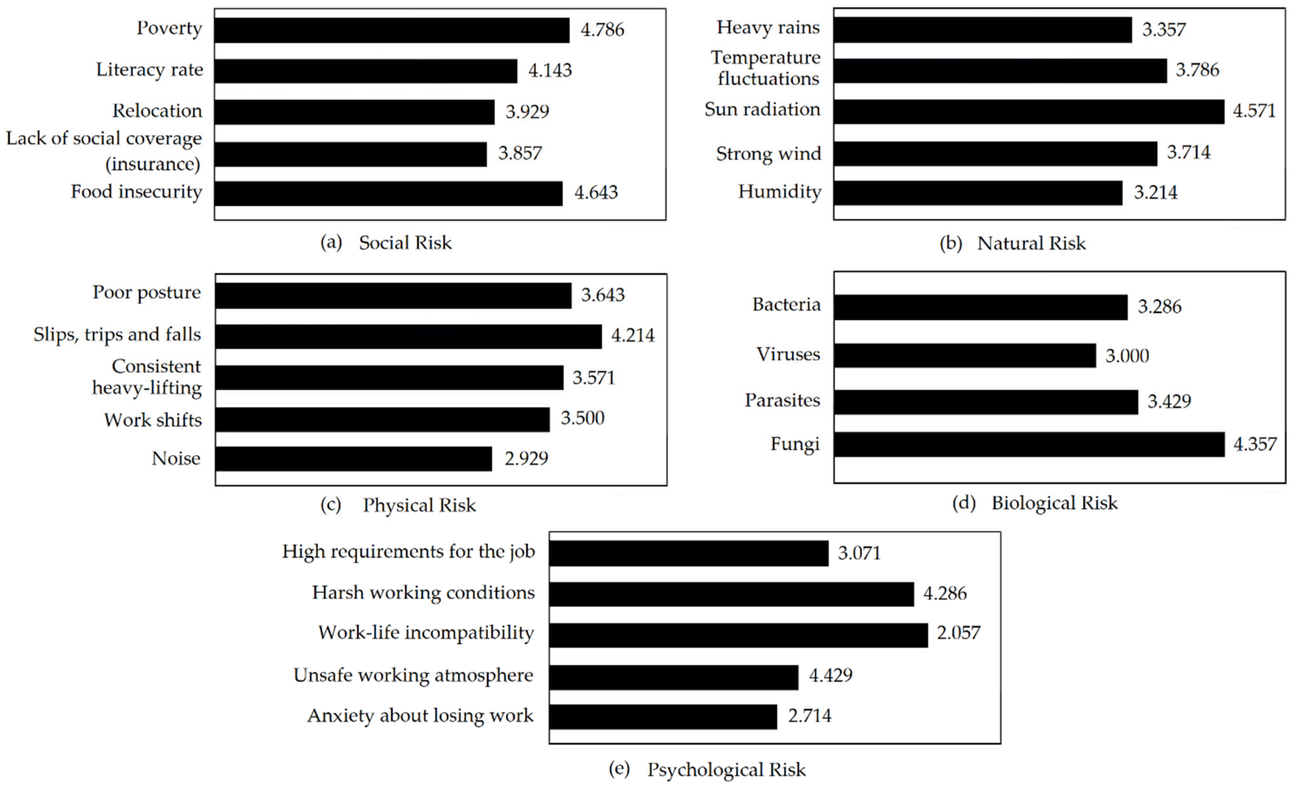

Figure 5. Rankings of the sub-factors based on their performance (IPA).

4.6. Improvement Assessment Analysis (IPA)

Among the factors with high importance and performance are 'poverty', 'slips, trips and falls', 'fungi', and 'harsh working conditions' (Figure 6). High importance but low-performance factors include 'poor posture', 'consistent heavy lifting', 'work shifts', and 'high requirements for the job'. Among the factors with low importance and performance are 'heavy rains', 'strong winds', 'humidity', 'noise', 'bacteria', 'viruses', 'parallels', 'work-life incompatibility', and 'anything about loss of work'. Despite low importance, there are factors with high performance, such as 'literature rate', 'relocation', 'lack of social coverage (insurance)', 'food security', 'temperature volatility', 'sun radiation', and 'unsafe working atmosphere' (Table 4).

Table 4. IPA output.

Code	Risk Sub-Factors	Importance Weights (%)	Performance Weights (%)	Quadrant
a1	Poverty	0.074	4.786	1
a2	Literacy rate	0.034	4.143	4
a3	Relocation	0.009	3.929	4
a4	Lack of social coverage (insurance)	0.012	3.857	4
a5	Food insecurity	0.023	4.643	4

Table 4. *Cont.*

Code	Risk Sub-Factors	Importance Weights (%)	Performance Weights (%)	Quadrant
b1	Heavy rains	0.017	3.357	3
b2	Temperature fluctuations	0.014	3.786	4
b3	Sun radiation	0.020	4.571	4
b4	Strong wind	0.004	3.714	3
b5	Humidity	0.003	3.214	3
c1	Poor posture	0.201	3.643	2
c2	Slips, trips and falls	0.117	4.214	1
c3	Consistent heavy-lifting	0.072	3.571	2
c4	Work shifts	0.047	3.500	2
c5	Noise	0.030	2.929	3
d1	Bacteria	0.025	3.286	3
d2	Viruses	0.012	3.000	3
d3	Parasites	0.007	3.429	3
d4	Fungi	0.044	4.357	1
e1	High requirements for job	0.110	3.071	2
e2	Harsh working conditions	0.055	4.286	1
e3	Work-life incompatibility	0.021	2.857	3
e4	Unsafe working atmosphere	0.034	4.429	4
e5	Anxiety about losing work	0.015	2.714	3

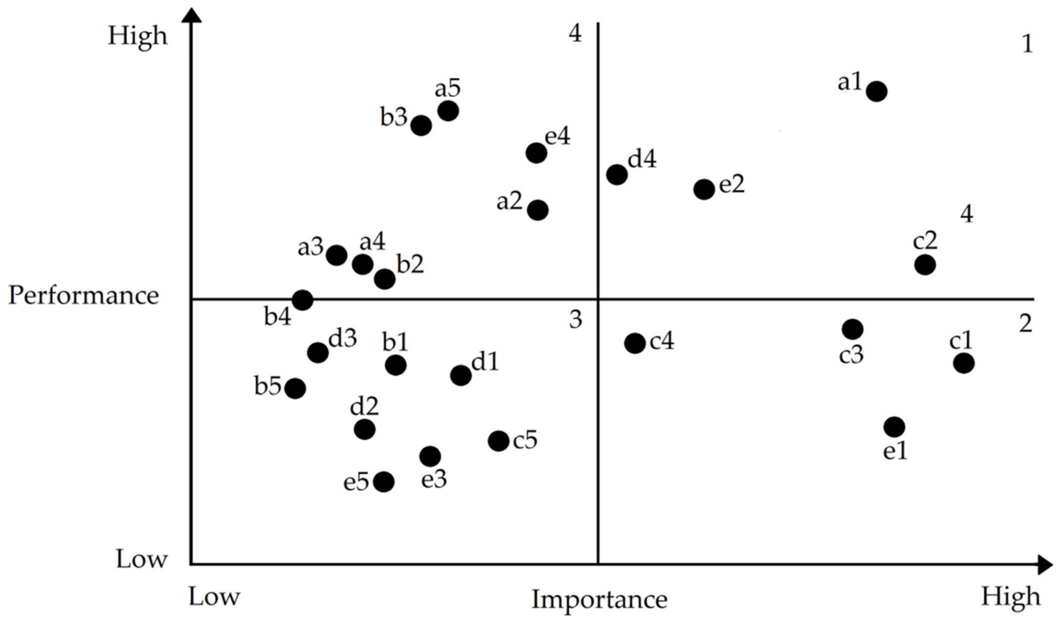

Figure 6. Improvement assessment analysis (IPA).

5. Discussion

This section presents a comprehensive discussion of occupational health risks faced by Chinese fishermen. We focus primarily on the physical risk faced by Chinese fishermen since it is the most significant risk and summarize the other risks. At the end of this section, we present a general discussion and implications of this study.

5.1. Physical Risks

Our survey shows fishermen are more likely to face physical risks than any other type of risk (Table 2). Many studies support this outcome [58]. The most significant physical risk faced by fishermen is poor posture, according to AHP output (Figure 4). IPA also ranked physical risk as the greatest risk type (Table 3). This risk occurs because a variety of actions are performed by fishermen, such as pulling, dragging, lifting, etc. As a result, they adopt many poor postures based on their actions. There are times when fishermen use their hands, wrists, and arms more while the rest of their bodies remain static. Sometimes, whole body movements occur, for example, when dragging fishing gear [59]. Our bodies burn ATP (adenosine triphosphate) to contract muscles as their energy currency. As ATP is utilized in the body, anaerobic metabolism produces lactic acid. Muscle performance and fatigue are reduced when lactic acid accumulates in the muscles. Poor posture is more likely to occur when fishermen are fatigued. The tendons can be directly damaged by repetitive work and stretching. Body posture is affected when working in a small space. This risk cannot be completely avoided, but it can be controlled. Fishermen should be taught to work more ergonomically according to ergonomic principles [60]. A second way to encounter this risk type is to redesign tools and machines [61]. According to studies, putting ergonomic principles into practice makes heavy lifting safer and more efficient. It is possible to reduce engine noise by performing regular maintenance. Moreover, earplugs around working engines are recommended to reduce noise exposure [47].

The health of fishermen is affected by a wide range of risks, including slips, weather, fatigue, etc., [29] which is the second most important physical risk (Figure 4). Published literature has documented this type of physical risk frequently. Onboard injuries are often caused by fatigue [37]. Fatigue is caused by overwork, manual labor, and a slick workplace environment. It affects the fishers' efficiency, posture, and sleeping patterns. To reduce fatigue among fishermen, ergonomics must decrease workload through automated processes [47]. In many cases, slips go unreported because they are so common and treated as an ordinary occurrence [62]. One study found that 70% of injuries are not generally reported [63]. Physical risks can be reduced by taking various measures, including not overworking, preventing motion sickness, reducing noise, sleeping uninterrupted and automating tasks [47]. Slipping has been documented as a common cause of injuries in numerous studies. Snow, ice, water, oils, tissues of fish, and other factors can damage deck floors regardless of their non-slip coatings. Fishing shoes and movement patterns, as well as the ocean environment, may contribute to these issues. The AHP ranked poor posture as the biggest risk, while the IPA ranked slips, trips, and falls as the biggest risk in increasing management performance (Figure 5). To improve management performance of slips, trips and falls, scientific studies suggest using special boots having slip-resistant quality [64]. Furthermore, fall prevention measures include slip-resistant paint and grippe footwear [65]. Research has urged engineers to design the equipment according to ergonomic principles to address musculoskeletal issues. The fishermen will benefit greatly from this by performing better in a limited space [66].

5.2. Natural Risks

Natural risks also affect fishermen's health adversely (Table 2). The existing literature frequently reports this type of risk. Fishermen often sustain occupational injuries due to harsh weather conditions and equipment failures [62]. In the aftermath of natural crises, fishermen should be better prepared for the effects of climate change [67]. The livelihoods of fishermen can be revitalized by programs designed to adapt to climate change, according to some experts. Governments must be involved to make adaptation initiatives successful in the long run, and partnerships with stakeholders must be strengthened [68]. In order to mitigate this type of risk, several proposals have been proposed. To reduce natural risks, several measures can be taken. The list includes buoyancy aids, fishing in optimal conditions, covering lips and eyes with a hat, locating devices, shouting a Mayday signal, wearing sunscreen, wearing UV-protective eyewear, and swimming skills [47]. Sun radiation is the biggest type of natural risk which fishermen encounter (Figure 4). Ocular diseases, particularly cataracts, can be caused by exposure to sunlight. It has been found that brimmed hats reduce ultraviolet radiation exposure [69]. Brimmed hats are recommended to protect from the deleterious effects of sunlight. In China, fishermen live much worse lives than their counterparts [70]. Therefore, policies that help fishermen improve their quality of life are recommended. By minimizing flooding, ships can control humidity. Utilizing specialized tank monitors can assist in achieving this goal [71].

5.3. Social Risks

Social risks are the third type of risk Chinese fishermen face (Table 2). In order to deal with this type of risk, a variety of solutions are proposed. In order to increase management of social risks, poverty is the most important subtype (Figure 4). A number of management measures have been taken by the Chinese government to address this type of risk. The primary goal is to improve the quality of life. Aside from that, it is also a plan to increase the income of Chinese laborers. The income gap between rich and poor will therefore decrease in China in the future, thereby reducing poverty. Several studies have claimed that insurance plays both a pre-and post-occurrence role in reducing the effects of natural risks [72]. Despite this, because of the unclear regulations, ignorance, cost of settling claims, and complicated approval procedures, many fishermen avoided making claims [73]. Occasionally, fishermen can file insurance claims when natural climate conditions adversely affect them. Fishermen are rarely insured or remunerated for their losses [74]. However, China has a very interesting and developed fishery insurance system. However, still many sections of this system need to be improved [8].

5.4. Psychological Risks

Psychological risk is the second most significant category of risk affecting the health of fishermen (Table 2). Even though swimming skills are very critical to fishers (Figure 4), 13% of them cannot swim, according to one study [63]. The inability to swim has led to the death of several fishers in the past. It is estimated that a significant percentage of fishermen familiar with swimming do not have complete swimming skills [74]. Using protective devices is also neglected. Several reasons for this include working in a confined space, working around gear, and getting tangled in fishing lines. These problems have been solved by many new designs [75]. According to research, different floatation devices are recommended for different vessels [76]. It is difficult to get fishers to adhere to the use of floatation devices. It is possible, however, to solve this problem through campaigns [70]. Work–life incompatibility and harsh working conditions need to be mitigated for better performance management of this type of risk (Figure 5). According to Murrey et al., anxiety and uncertainty about work contributed to occupational injuries among fishermen [77]. Research recommends job hazard analysis when dealing with psychological risks [78]. It is possible to reduce risks by designing ships appropriately [79]. Risks can be reduced if old ships are replaced with new ones in time [80]. Psychological risks can be reduced through a variety of measures. These measures include re-designing work, protecting against noise, analyzing workplace hazards, strengthening insurance coverage, and sharing innovative ideas [47]. Furthermore, fishermen need fish box lifters on ships as well. Stabilization tanks can reduce ship movement, thereby decreasing falls [81]. A ship's movement may facilitate lifting and lowering loads [82].

5.5. Biological Risks

The health of fishermen is affected by a number of biological factors (Table 3), most of which are connected to their skin, including allergic contact dermatitis. Among the skin conditions that occur frequently is irritant contact dermatitis. In order to protect them from these skin diseases, gloves are a good option [47]. Because of the environment and the materials they work with, fishermen are particularly prone to finger and hand ailments. It is possible for them to be injured by a variety of things, such as fish spines. A variety of methods can be used to reduce biological risks, including first aid knowledge, protective equipment wear, and treating injuries immediately [47].

5.6. General Discussion

Fishers do not actively report the risks they face, which underpins their importance. They indeed feel danger, but they rarely discuss it with others [63]. It is, therefore, important to encourage them to speak about this issue [83]. Moreover, it has also been found that fishermen are reluctant to seek medical attention [74]. Despite being aware of various risks, fishers do not attempt to address them. It is, therefore, necessary to develop a learning culture related to risk perception [84]. Instead of giving written guidelines to fishers, it is better to directly instruct them on safety measures [81]. It is important to increase fishermen's health awareness, which can be achieved through training [85].

It is important to note that the analytical methods applied lack perfection. In particular, their weights are inexplicably high, preventing them from accurately quantifying attributes. Occasionally, mathematically impossible decisions can be reached through these methods. Due to this, it is not legitimate to use these methods in such a scenario. In these methods, inputs must be correlated with outputs. However, these methods lack an explicit relationship between the two. Furthermore, the decision-making process is based exclusively on the preferences of stakeholders, disregarding threats and ambiguities. Moreover, the magnitude of the costs and benefits is also overlooked **[86]**. The criteria employed in these methods are inadequate **[87]**. It is important to mention that these shortcomings are not indicative that these methods produce unreliable results. Instead, these methods are popular around the globe for optimizing resource allocation under a variety of risks. Due to their strengths, we utilized Fuzzy AHP and IPA to conduct this study.

Weights are commonly used in statistical analysis and have been explored by a number of scholars [88,89]. Using weights in analyses of survey results, main and sub-factors, has been shown to be useful by their studies. Such as, it is important to use weights when analyzing survey statistics to avoid serious bias in interpreting the results, that is why we have used weights in this study. It must be noted that in self-weighted samples, the results of both weighed and unweighted estimators are identical. The estimations of a given population should not be affected significantly by whether the weights are included in the sample design or not if the sample design is adequate. The use of estimators that are weighted may yield more accurate conclusions when the design of the survey is useful [90]. Several weighted variables were used in this study, indicating that the design of the study was adequate and the results were reliable.

5.7. Implications

Insights provided by this study have several implications for the administration that merit consideration and are practical. These findings can be a reference and a guide when making strategic decisions. Such as, this study provides empirical evidence that physical risk poses the greatest risk to a fisherman's health. In addition, various main and subcategories of risks are also identified. A comprehensive understanding of the existing risks is essential to creating a robust risk mitigation strategy. The absence of rating and priority can lead to risk management pitfalls. Moreover, an essential outcome of this study is pinpointing critical areas for improving performance management. Consequently, resource wastage can be reduced, and resource utilization can be enhanced. Risk mitigation solutions are also discussed in this study. Indeed, improved occupational health of fishermen will boost the fisheries sector's development. In turn, this will benefit the country's economy. When it comes to improving management practices, there are a number of methods that can be used, but finding the most effective method is not an easy task. Management efforts cannot be successful if the main risks and sub-categories are not identified. In this way, the study findings guide developing a reliable management plan to improve fishermen's occupational health.

6. Conclusions

A quarter of the world's fishermen are Chinese. Unfortunately, the fisheries industry in China has the highest accident rate among occupations. It is well documented that

Chinese fishermen face a variety of occupational health risks. However, their occupational health risks are rarely studied despite being extremely critical for the sustainable development of the fisheries sector. In this study, we attempt for the first time to categorize and prioritize multiple types of health risks posed by these fishermen. Results have revealed that commercial fishermen's health is affected by five main risk factors, natural (0.058), biological (0.088), social (0.152), psychological (0.234), and physical (0.468), which are arranged from the least to the most significant risk factors. As for the performance of the main risk factors, physical risk (4.786) was ranked first, followed by social risk (4.571), psychological risk (4.214), biological risk (4.000), and natural risk (3.429). However, this study has some limitations, as with most studies published so far. As the data were compiled only from Zhejiang, the results cannot be generalized to other parts of China. Thus, large-scale data may be used in upcoming studies. Furthermore, a relatively long-term performance analysis is necessary to understand occupational health risk management and performance. Quantitative approaches that are more innovative can be used in future research. Moreover, it is important to note that the analytical methods applied in this study lack perfection. In particular, their weights are inexplicably high, preventing them from accurately quantifying attributes. Occasionally, mathematically impossible decisions can be reached through these methods. Due to this, it is not legitimate to use these methods in such a scenario. In these methods, inputs must be correlated with outputs. However, these methods lack an explicit relationship between the two. Furthermore, the decision-making process is based exclusively on the preferences of stakeholders, disregarding threats and ambiguities. Moreover, the magnitude of the costs and benefits is also overlooked [86]. The criteria employed in these methods are inadequate [87]. It is important to mention that these shortcomings are not indicative that these methods produce unreliable results. Instead, these methods are popular around the globe for optimizing resource allocation under a variety of risks. Due to their strengths, we utilized Fuzzy AHP and IPA to conduct this study.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su142013100/s1. Sample questionnaires used to conduct this study.

Author Contributions: Conceptualization, J.-L.Y. and M.M.; methodology, Y.-J.X.; validation, M.M.; formal analysis, M.M.; investigation, J.-L.Y.; resources, Y.-J.X.; data curation, Y.-J.X.; writing—original draft preparation, J.-L.Y. and M.M.; writing—review and editing, Y.-J.X.; visualization, J.-L.Y.; funding acquisition, J.-L.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by National Philosophy and Social Science Foundation of China, "Research on the Collaborative Management of the Ecology and Environment of Bohai Sea under the Guidance of Land-Sea Overall Planning" (Grant # 19CJY023).

Institutional Review Board Statement: Ethical review and approval were waived for this study because the survey with human subjects consisted of non-invasive items.

Informed Consent Statement: Informed consent was obtained from all the subjects involved in the study.

Data Availability Statement: The data presented in this research are not publicly available due to participant's privacy.

Conflicts of Interest: The authors declare no conflict of interest.

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