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Priority decision of risk management for Chinese fisheries by using an analytic hierarchy process (AHP) approach

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This study aims to (1) identify risk types faced by the Chinese fisheries; and (2) give priority ranks to the risks and their sub-types for better management. For this purpose, data was collected from fishery researchers/experts working in Shandong, Fujian, Liaoning, and Guangdong provinces of China through questionnaire based survey. In total, 33 questionnaires were obtained among which only 25 questionnaires, consistency ratio (CR) value below than 0.1, were employed in this study. Data was statistically analyzed by using the Analytical Hierarchy Process (AHP). Obtained results indicate that Chinese fisheries is facing five diverse risk types, *viz*., natural risk, ecological risk, market risk, technical risk, and management risk. The calculated rank and importance of these risks types are management risk (1 and 0.509), ecological risk (2 and 0.220), technical risk (3 and 0.131), natural risk (4 and 0.076), and market risk (5 and 0.063). On the other hand, overfishing is the biggest risk sub-type faced by Chinese fisheries followed by lack of knowledge and hazardous inorganics. Overall, 18 risk sub-types are identified in this study. The estimated rank and importance of top 3 risk sub-types are overfishing (1 and 0.239), lack of knowledge (2 and 0.169), and hazardous inorganics (3 and 0.130).

[**Keywords**: China, Fisheries, Priority decision, Risk management, Risk ranking]

Introduction

The People's Republic of China (hereinafter denoted as China) is a leading fish producer, wild as well as cultivated fish, in the world. Reported figures indicate the fish production has increased manifolds from 1950 to 2000 which can be considered as a great accomplishment[1]. However, on the other side, this success has put the Chinese fisheries into trouble by exposing it to various types of risks. Traditionally, the word "risk" began to pop up in fishery resource management studies through 1990s[2]. Fundamentally, this word represents a concept and depends upon various factors such as variation or anticipated state in the outside and scanty knowledge about it. Briefly speaking, risk is acuity about some bad happening[3]. Studies indicate that three factors, *viz*., collapse of numerous fisheries in the past, severe decline in fisheries biomass and increasing public awareness about fisheries industry, are responsible for the appearance of this term in the scientific literature[4]. In the past, these risks were not perceived until the start of 2000 when capture fisheries flinch to show declining production and fishing vessels twitch overcapitalization. These happenings got some attention of the researchers and studies related to different types of risks faced by Chinese fisheries started to pop up in the published literature. Thus, several researchers started to contribute in this field of research. For instance, Sun Yingshi[5] determined fatality accidents of fishermen caused by the malfunction of operational gears as major kinds of risks associated with the fisheries. Chunfen & Jie[6] studied fisheries insurance system and declared it a big risk faced by Chinese fisheries. Although, these studies and some other, a meager literature, describes risks faced by the Chinese fisheries and suggest possible solutions[7], however, some problems are associated with this literature. First, this literature is exclusively in Chinese and due to language barrier most of the information is not accessible out of China. Second, it mostly focuses on selected risk types and does not portray a broad picture by comparing various risk types and giving priority ranks for better and effective management. On the other hand, risk assessment studies are pivotal for making and prioritizing management strategies as is need for China, the largest fishing nation is the world.

Several statistical methods can be used for assessing the risks, along with their priority order, faced by the fisheries. However, the choice of the method by researchers mostly relies onto reliability, applicability and investigated problems. Among all the multi-criteria approaches used for decision making by considering compound objectives, the Analytical Hierarchy Process (AHP) is a very commonly employed and the best known statistical technique[8]. It helps to make decisions about suitable choices among complex situations or to measure consistency performance[9]. In 1977, Saaty first time proposed AHP method and revised in subsequent years, *i.e*, 1980 and 1988[10-12]. AHP establishes pairwise comparisons and apprises scores and weights according to which policy makers can recognize order wise important criteria. Detailed AHP modelling is presented in materials and methods section. This method has been used in several decision making studies. The popularity of this method relies on its several advantages over the other statistical routines. First, this method is flexible; offers intuitive appeal and check discrepancies. Second, it builds hierarchy which makes every criterion very clear. Third, it reduces decision making bias. Fourth, it uses pairwise comparison to draw group decision making. Fifth, it has an ability to deal with the risk and uncertainty of the analysis[13-14]. By considering these advantages, AHP method is used in this study.

Purpose of this study includes: (1) to classify types of risk encountered by Chinese fisheries; and (2) give priority ranks to the risks faced by Chinese fisheries and their sub-types.

Risks faced by the Chinese fisheries

Based on the published literature risks faced by Chinese fisheries can be classified into five different categories, *viz*., natural, ecological, market, technical and management. Following is the review of literature related to these risk factors.

Natural risk

Natural calamities occur in every part of the world. No doubt, these catastrophes have a potential to affect the fishery resources. Climate changes have enormous effects on aquatic habitats by rising water temperatures, increasing sea level and amplifying tropical hurricanes and storms. Coastal zone vulnerabilities include fish profile changes and reduction in coastal wetlands[15]. Rising sea levels induced by climate changes confer potential severe threats to mangroves. In the past, Chinese fisheries have suffered from heavy losses because of several natural disasters such as tsunamis, typhoons, etc. Thus, natural risks are the major risk factors affecting Chinese fishery[16].

Ecological risk

Published literature indicates that Chinese fishery is exposed to several different kinds of ecological risks. For instance, research indicates that fish farming activities or fish enhancement programs confer several ecological risks. These risks may harm the genetic diversity in the wild stocks[17]. It is also reported that global warming is affecting the survival of marine organisms. Environmental disasters for instance marine eutrophication, release of toxins, radioactive matters abandoned into the ocean, gas and oil leakage, and solid waste pollution are posing great threat to protection of marine fishery resources. Spilled oil into the sea has proved chaos to marine life. Moreover, aquatic products, polluted with mercury, causing human health issues are usually a subject of research in China. In this regard, scientific studies demonstrate harmful impact of mercury on human health[18]. Similarly, it is found that pollution is proving havoc for aquatic environments in Asian counties including China. Role of zinc in pollution enhancement is also found to be critical[19]. Speedy construction of coastal ports occupies large sea areas where fishermen live. Development of islands also increase stress on aquatic environmental resources and its carrying capacity[20]. Land pollutants release has provoked worsening of aquatic environment. On the other hand, this provoked emission of land pollutants is resulting in the decline of marine resources. For sustainable development of ecosystem, usually plans are made. However, these plans mostly have conflict between their written aims and objectives making them full of ambiguity. Usually, developed countries have ecological risk management strategy which are based on the interventions of harvest strategy and risk assessment frameworks[21].

Market risk

Supply chain of fish and fish products coupled with rising market demand brings catastrophe to fishery resources and results in overharvesting. Studies conclude that pace and scale of fish meat trade is the primary factor responsible for overfishing. Exploring and understanding these risks is crucial to manage market risk[22]. According to several research studies, Chinese fisheries are also facing market risk. It is found that changes in fishery production decision-making, change in market, etc. may cause losses. Fisheries sector is confronting diverse risks types, *viz*., market risk, natural risk, management risk and technical risk. Among these risk types, market is significant. Rising fishery prices and production means result in the increase of fishermen's production and operation risk[22]. Absence of financing coupled with capital circulation problem is main factors impeaching aquaculture development. Mostly, farmers have low risk tolerance and there are certain risks in the project. Moreover, industries having high risk are mostly avoided by the private capital. That's why these industries lack stable policy[23]. However, China is recognized as a high paying subsidy country in the world. However, these heavily provided subsidies are pushing ongoing regime towards overcapacity resulting in overharvesting of fishery resources, thus, pertaining to another risk type faced by fisheries sector[24].

Technical risk

Fishermen must face both the natural risks and social risks. Natural risks include storm surges, typhoons, and red tides, whereas, social risks comprise management as well as disease risks[6]. Risks faced by aquaculture are due to technical risks, natural disaster risk, and social risks. It has been found that breeding technique problems or invasive species can result in lower fish growth or even death[25]. Expansion in marine fishing area, boat horsepower and low-quality of fishermen increases risk of marine fisheries production[7]. Although, deep water cage culture started in Hainan province of China during 1998, however, pace and scale of development is still infancy. This impediment in growth is nurtured by technical risks. These risks also include risks associated with fishing technology and processes such as soak time, set depth, fishing time, target species, caught fish handling process and bait[26]. These risks have varying degree of impact on fisheries and thus their understanding is necessary for managing risk. For instance, use of circle hooks as well as nylon leaders can help to decrease fish mortalities. Similarly, changing net tension and mesh size can be an effective measure to reduce susceptibility towards certain meshing. Improvement in technology can reduce risk faced by the fisheries sector and improve its performance[27].

Management risk

Fishery insurance system should be necessarily in accordance with national situations. However, on the other side, incentives offered can shape behavior of the fishermen[28]. Fishermen differ from each other with respect to their experience, knowledge and ability to adjust. Thus, implementing same standard risk management practices cannot bring optimal management goals. Overexploitation of fishery resources is resulting in the decline of fish production. In this regard, capacity enhancing fisheries subsidies policies have played vital role. China is one among the top five countries of the world having fisheries industry heavily supported by subsidies. This thrust in subsidies has resulted in overharvesting of fishery resources[24]. Overfishing is reducing shark fisheries, both target and by-catch, swiftly resulting in resource decline and extinction. In China, national policy structure brings recessive risks to fishermen. Thus, formulation and implementation of stable, compatible and perfect management based insurance systems in China is prerequisite to strengthen fisheries[6].

Materials and Methods

Data collection

This study was conducted from February to May 2019 to evaluate the risk perception ranks in the Chinese aquaculture sector and identify risk management priority factors perceived by an aquaculture expert (researchers) population scattered across different regions in China; this was done by using a questionnaire survey. Face-to-face interviews, based on questionnaire, were conducted to confirm consistency of questionnaire and accuracy of data. A total of 33 completed questionnaires were collected. Among them, 8 were excluded because their CR value was more than 0.1. The remaining 25 questionnaires, with CR less than 0.1, were analyzed using the AHP software Expert Choice 2000. The consistency ratio (CR) is calculated from AHP results, and CR value lower than 0.1 indicates considerably high logical consistency among expert population evaluated[29].

Data analysis

As aforementioned, questionnaire data obtained for this study was statistically analyzed by AHP. Several renowned studies use this software to make choices between options[30]. This software uses linear additive model and axiom independence method. Among all the options (risk types) pairwise comparisons were made to calculate scores and weights. The process of AHP analysis was done in the following four steps:

Step 1: Decision problem structuring and criteria selection: At this step hierarchy was made by considering the problem (risk types). First, decision problem was decomposed into its basic parts. These parts were arranged into hierarchy into the top most (goal), intermediate (criteria) and the lowest level (options). Hierarchy was constructed by considering the problems affecting the options, attributes of the solution and participants of the problem. Thus, pairwise comparison matrix A for n objectives (n×n) were formed as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \text{(ref. 31)}$$

The above matrix presents a_{ij} values in pairwise comparison. Where, a_{ij} represents importance of i^{th} objective over j^{th} objective. For all i and j values, it is supposed that $a_{ii} = 1$ and $a_{ij} = 1/a_{ji}$.

Step 2: Pairwise comparison of criteria (weighing): Priority setting of the criteria was done by making pairwise comparison at this step. For this, weight was given to the criteria through a number from 1 to 9 which represented equal importance and extreme importance, correspondingly. On the other hand, reciprocal value of this number was assigned to the other criterion in a pair. Afterwards, weighing was normalized and averaged to get average weighing value for every criterion. For this purpose, each entry in column j of A was divided by the sum of the entries in column j. Thus, new matrix was obtained, Aw, in which entries sum will be 1 in every column. This matrix is presented as follows:

$$Aw = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \frac{a_{12}}{\sum a_{i2}} & \cdots & \frac{a_{1n}}{\sum a_{in}} \\ & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \frac{a_{n1}}{\sum a_{i1}} & \frac{a_{n2}}{\sum a_{i1}} & \cdots & \frac{a_{nn}}{\sum a_{in}} \end{bmatrix} \text{(ref. 31)}$$

Step 3: Pairwise comparison of options (scoring): Within every criterion, better option was given a score from 1 to 9 which represented equally good and absolutely better option, respectively. Reciprocal of this value was assigned to other option in a pairing. Later on, these scorings were normalized and averaged to get average scoring value for every criterion. This was done by computing value of c_i as average of entries in row i of Aw to produce column vector C.

$$C = \begin{bmatrix} c_1 \\ c_2 \\ \cdots \\ c_n \end{bmatrix} = \begin{bmatrix} \frac{\frac{a_{11}}{\sum a_{i1}}}{n} & \frac{\frac{a_{12}}{\sum a_{i2}}}{n} & \cdots & \frac{\frac{a_{1n}}{\sum a_{in}}}{n} \\ & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \frac{\frac{a_{n1}}{\sum a_{i1}}}{n} & \frac{\frac{a_{n2}}{\sum a_{i1}}}{n} & \cdots & \frac{\frac{a_{nn}}{\sum a_{in}}}{n} \end{bmatrix} \text{(ref. 31)}$$

Where, c_i shows relative degree of importance of i^{th} objective.

Step 4: Overall score for each option: In this final step of AHP analysis, option scores and criteria weights were combined to get overall score. Simple weighted summation method was applied to find options which satisfy the criteria according to their relative importance. At this final step, consistency of judgments in the pairwise comparison was checked. This process was done in four sub-steps which are described as follows:

1) Computed A.C. as follows:

$$A.C = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ \cdots \\ c_n \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ x_n \end{bmatrix} \text{(ref. 32)}$$

2) Estimated λ_{max} as follows:

$$\lambda_{max} = \frac{1}{n} \sum_{i-1}^{n} \frac{x_i}{c_i} \text{(ref. 32)}$$

Here, λ_{max} is the maximum eigenvalue of pairwise comparison matrix.

3) Computed consistency index (CI) as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \text{(ref. 32)}$$

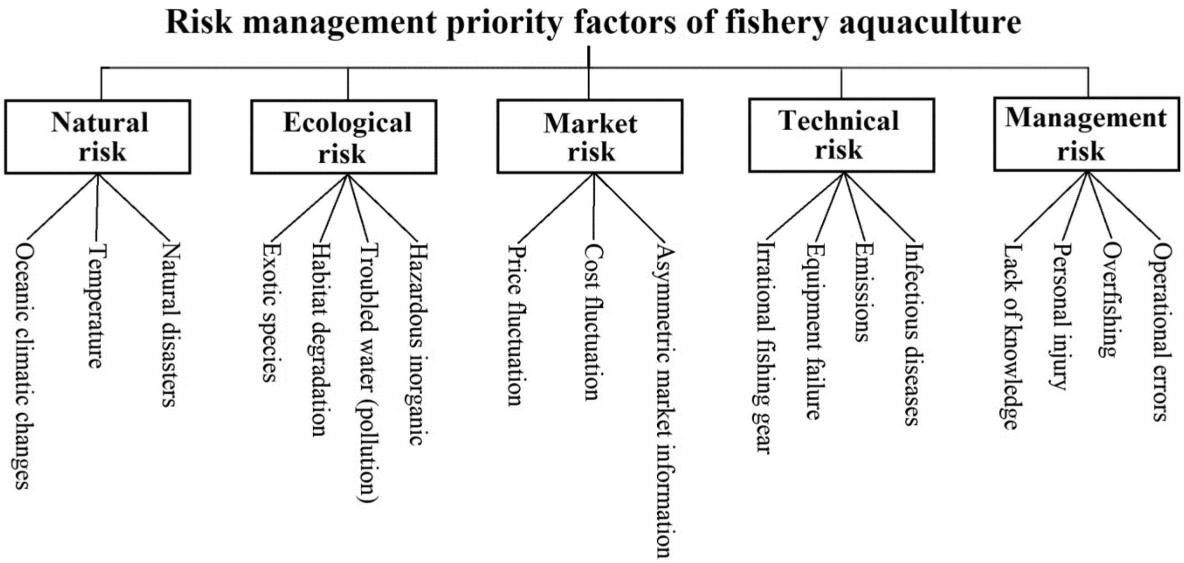

Fig. 1 — Risk management priority of fisheries in China

CR is estimated by dividing CI by value obtained from standard Random Consistency Index values represented as follows:

$$CR = \frac{CI}{RI} \text{ (ref. 31)}$$

The AHP analysis method used to derive the importance of “Risk management priority of Chinese fishery aquaculture” is presented in Figure 1.

Results

Considering the survey response results, there were 20 senior research fellows (80 %) and 5 associate research fellows (20 %). By years of experience, 5 respondents had “more than 5 years” (20 %), while 20 respondents had “more than 10 years” (80 %) of experience. By region, 9 respondents were from Shandong province (36.0 %), 7 from Fujian province (28.0 %), 5 from Liaoning province (20.0 %), while the remaining 4 were from Guangdong province (16.0 %). If we look at China fishery statistical yearbook (2016, 2017, 2018), the regions with the highest production in the field of fishery aquaculture were Shandong, Fujian, Guangdong, and Liaoning provinces, leading us to mainly focus on these regions, so as to ensure objectivity and fairness in the research (Table 1).

Table 1 — Frequency analysis

	Categories	Frequency	Percentage
Status	Senior research fellow	20	80.0
	Associate research fellow	5	20.0
Education	Ph.D	25	100.0
Working experience	> 5 years	5	20.0
	> 10 years	20	80.0
Region	Shandong province	9	36.0
	Fujian province	7	28.0
	Liaoning province	5	20.0
	Guangdong province	4	16.0
	Total	20	100.0

Table 2 — Relative importance analysis of upper hierarchical factors

Evaluation area	Importance	Ranking
Natural risk	0.076	4
Ecological risk	0.220	2
Market risk	0.063	5
Technical risk	0.131	3
Management risk	0.509	1
CR	.018	

Relative importance and priority ranking of main factors

From Table 2, relative importance and priority ranking of main factors, we can rank the order of importance to be as follows: Management risk (0.509), Ecological risk (0.220), Technical risk (0.131), Natural risk (0.076), Market risk (0.063), with CR value lower than 0.1, indicating consistency.

Relative importance and priority ranking of sub-factors

Natural risk

From Table S1, relative importance and priority ranking of minor factors in “Natural risk”, we can rank the order of importance to be as follows: natural disasters (0.662), oceanic climate changes (0.237), and temperature (0.101), with CR value of lower than 0.1, indicating consistency.

Ecological risk

From Table S2, relative importance and priority ranking of minor factors in "Ecological risk", we can rank the order of importance to be as follows: hazardous inorganic (0.590), habitat degradation (0.228), troubled water (pollution) (0.115), exotic species (0.067), with CR value of lower than 0.1, indicating consistency.

Market risk

If we examine Table S3, the relative importance and priority ranking of minor factors in "Market risk", we can rank the order of importance to be as follows: price fluctuation (0.538), cost fluctuation (0.348), and asymmetric market information (0.115), with CR value of lower than 0.1, indicating consistency.

Technical risk

If we examine Table S4, relative importance and priority ranking of minor factors in "Technical risk", we can rank the order of importance to be as follows: irrational fishing gear (0.553), infectious diseases (0.267), equipment failure (0.117), and emissions (0.064), with CR value of lower than 0.1, indicating consistency.

Management risk

From Table S5, relative importance and priority ranking of minor factors in "Management risk", we can rank the order of importance to be as follows: overfishing (0.469), lack of knowledge (0.332), personal injury (0.137), and operational errors (0.062), with CR value of lower than 0.1, indicating consistency.

Overall importance analysis results of sub-hierarchical factors

Taking into consideration the major factors for overall importance and priority ranking of sub-factors (Fig. 2), we can rank the order of importance to be as follows: overfishing (0.239), lack of knowledge (0.169), hazardous inorganics (0.130), irrational Fishing gear (0.073), personal injury (0.070), and natural disasters (0.050), with CR value of lower than 0.1, indicating consistency.

Discussion

This study finds that Chinese fisheries is facing five types of risks, *viz*., ecological, natural, market, management, and technical among which the management risk is the biggest risk. On the other hand, overfishing is the biggest risk sub-type faced by Chinese fisheries. Therefore, this section aims to describe fisheries management in China by focusing on overfishing and government steps taken in this regard. Later on, proposed risk management strategies are suggested to deal with the implications of this study, *i.e.*, management of various risks faced by Chinese fisheries. This is not the first time finding that Chinese fisheries is exposed to overfishing, rather, a plethora of published literature confirms this[33]. Overfishing is actually a result of significant rise in fishing effort. In the past, Chinese government's fisheries promotion policies during the 1950's and the 1960's resulted rapid increase in fishing effort. It is reported that before 1980, the Chinese fisheries started to face the risk of overfishing[34]. However, there were no adequate fisheries management measures at that time to manage overfishing. As a result of this regime, the catch composition of fisheries started to change dramatically[35]. In addition to this declining production, habitat destruction of famous fishery grounds also started to occur[34].

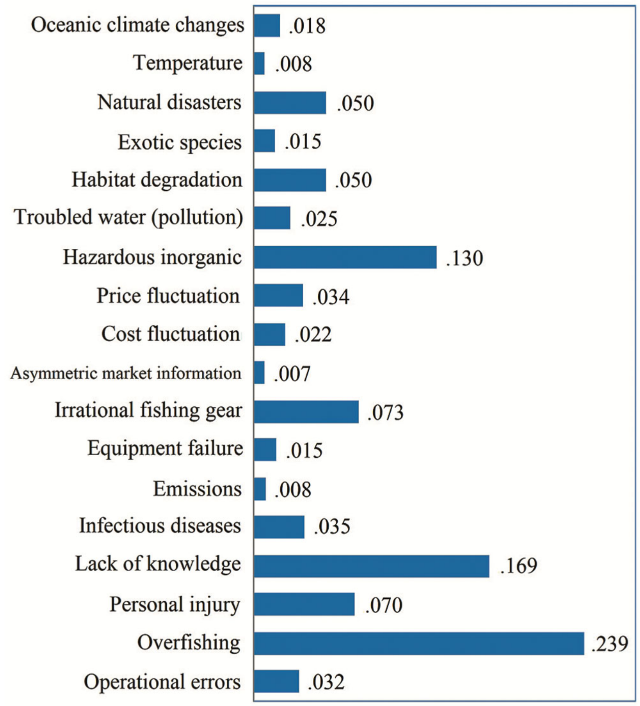

Fig. 2 — Relative importance of sub-hierarchical factors final analysis

In order to encounter these emerging risks, Chinese government in 1979 introduced permit system for fishing. This system was designed to control the fish catch, *i.e*., overfishing. In the coming years fishing effort and fishing catch showed rising trend. Another attempt to manage fisheries was done in 1987 through a policy named as "single control". The aim of this policy was to control the aggregate hp (horse power) by introducing quota system. However, still the situation could not improve[31]. In 1995, mid-summer fishing moratorium was started in as an attempt to control capacity utilization. As a result of this moratorium, during the summer season, a ban was imposed on fishing in the East China Sea (from June 1 to August 1) and the Yellow Sea (from June 1 to September 16). Again due to several reasons, the expected benefits from this moratorium were not achieved[36]. To improve this situation another policy, *viz*., double control was implemented in 1997. This policy strived do limit hp along with fishing effort. Despite introducing double control policy, desired results were not obtained because of several factors such as input substitution, local protectionism and advancement in fishing technology[34].

In 1999, Ministry of Agriculture (MOA) proposed a new policy *viz*., zero growth. This policy was aimed to keep the fish catch at the same level in coming years and proved to be an effective policy to protect dwindling fishery resources. Studies conclude that since 1985, IUU (illegal, unregulated and unreported) fishing in China has increased considerably. According to the fishing vessel census conducted in 2000, 27.5 % of the fishing vessels did not have compulsory documents required for fishing. These excessive illegal fishing vessels were responsible for excessive fishing effort and overfishing[3]. Since 2001, the Chinese government has started a program to restore fishery resources by constructing artificial reefs. According to some studies, this action of the government has played its role positively in restoring fishery resources[37]. Thus, in order to further control overfishing, during the period between 2003 and 2010, fishing boat buyback program was launched. The target was to reduce the number fishing vessels and capacity utilization by allotting quota to each province[7]. Moreover, in 2004, minimum mesh size regulation was fully implemented in China[38].

But, these regulations have several problems with them such as meager legally binding standards, no rules related to crabs and shrimps, need updating etc. It is reported that despite all of these measures, the fishing effort, *i.e*., fishermen has tripled from 1980 (1,224,000) to 2011 (3,690,000). Total engine power of fishing vessels is increasing consistently[39]. In order to encounter the effect of overfishing, in the past, China has implemented several fishery resource enhancement programs. However, the pace and scale of these programs have increased considerably during the last decade under the directions of MOA program. According to some studies, these enhancement programs have played their vital role to recover fishery resource, however, until now; no any systematic study confirms this[40].

In order to cope up with diverse risk types faced by Chinese fisheries, various strategies based on scientific published literature can be proposed. For instance, simple method to cope with risk is known as Precautionary Principle. According to this method, if benefit is greater than cost, then certain activity decision is followed[3]. This principle suggests taking action when some convincing evidence proves that the action is harmless. Thus, most of the risk management practices involve Precautionary Principle[41]. This principle also proposes to conserve population by avoiding the risk of its collapse or economic downfall. It also recommends those activities which do not harm socio-ecological systems[42]. Thus, following this principle not only fisheries resource is safeguarded but it is biologically protected too. Moreover, for managing economic risk in fisheries, transfer of risk towards another party through insurance policies is a good option[3]. The transfer of risk is done because it is expected that other party will better handle or bear it *i.e*., Pareto efficiency. However, managing risk through insurance is not common. This management practice mostly exists in developed countries in different forms such as personal safety and health, production, market, asset insurance etc.[43]. However, with respect to Chinese fisheries this insurance system of developed counties is suggested to manage economic risks faced by this sector.

Sometimes, fisheries risk management is done by diversification and portfolio method. In this method, fishery assets such as fish species, inter alia, financial securities etc. are clustered into various groups. The group which is expected to deliver the best management performance is selected[44]. For the identification of the best group, an analysis known as portfolio analysis is performed. Efficiency frontier is an important output estimated by this analysis on which the best group is recognized[3]. A wealth of literature denotes the application of diversification and portfolio methods to manage fisheries around the globe. There is a variation in the revenue of fisheries because of price fluctuation and it is generally known as market risk[45]. To encounter price risk in fisheries, various methods are recommended. These methods include forward contracting and futures, market timing and enterprise integration[30]. Fish buyers and sellers can sign contracts to fix price for coming time. This will ensure price stability and remove counter party risk. Hedging price movement method can also be employed to nullify this risk. Consistent supply of fish products in the market over time, *i.e.*, market timing can encounter price risk. Moreover, internalization and consolidation of the enterprise through vertical and horizontal integration also abolishes this risk[46]. Some studies also suggest the introduction of mobile phone to reduce this risk and enhance fish productivity[45]. This strategy can be studied and implemented in China to manage price risk.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at http://nopr.niscair.res.in/jinfo/ijms/IJMS_50(05)410-418_SupplData.pdf

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Conflict of Interest

There is no conflict of interest to carry out this research work.

Author Contributions

YH & CZ performed statistical analysis and wrote the manuscript. MM gave suggestions and provided necessary materials for this study. CS constructed tables and figures and revised several parts of the manuscript.

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