Risk Management of Production Fluctuations in Sea Fish Supply Chain: A Climate Change Perspective in Bangladesh

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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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Approval

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Abstract/ Executive Summary

Climate change impacts on supply chain is a burning issue in the new era of global business. Sea fishes play a vital role in the livelihood and it becomes an essential source of food with nutrients for the people of Bangladesh. However, no remarkable research work has been found regarding climate change impacts on the production fluctuations in sea fish supply chain in Bangladesh. That's why this research addresses the risks associated with climate change and proper risk management process of production fluctuations in sea fish supply chain. In this research, a case study has been carried out to demonstrate the entire supply chain of sea fishes from fishermen to final consumers through survey research techniques. After that, risks are identified from climate change perspective which are flood and cyclone through several data analysis techniques and consequently following identified risks are evaluated through the case study data analysis. Finally, risk treatment strategies have been selected with proper detailed guidelines which can be implemented according to proposed strategies additionally metrices associated with production fluctuations in sea fish supply chain have been proposed for continuous review and monitoring for proper risk management of sea fish supply chain.

Keywords: Climate Change; Production Fluctuations, Sea Fish Supply chain; Supply Chain Risk Management.

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List of Acronyms

IPCC	Intergovernmental Panel on Climate Change
AR6	Sixth Assessment Report
GDP	Gross Domestic Product
DoF	Department of Fisheries
EEZ	Exclusive Economic Zone
ITLOS	International Tribunal for the Law of the Sea
UNCLOS	United Nations Convention on the Law of the Sea
ISO	International Organization for Standardization
WMO	World Metrological Organization
SCRM	Supply Chain Risk Management
BBS	Bangladesh Bureau of Statistics
SWC	Storm Warning Centre
FFWC	Flood Forecasting and Warning Centre
BMD	Bangladesh Metrological department
CPFR	Collaborative Planning, Forecasting and Replenishment
RFID	Radio Frequency Identification

Chapter 1

Introduction

1.1 Background

Climate change currently poses as one of the greatest threats to global biodiversity [1]. According to sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC-AR6) climate change has caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater, cryosphere and coastal and open ocean ecosystems [2]. Based on the Global Climate Risk Index, Bangladesh is ranked seventh in terms of vulnerability to climate risk. Bangladesh is ranked 18th in terms of national vulnerability to the impacts of climate change on marine fisheries [3] because of its low-lying topography, climate-sensitive agrarian economy, widespread poverty, high population density, and poor governance.

The fisheries sector plays a vital role in the economy of Bangladesh, accounting for 2.43 percent of GDP (22.14 percent of agricultural GDP), 1.05 percent of export earnings and more than 60 percent of the animal protein supply in people's diets. Fishing provides direct or indirect employment to 12 percent of the total population [4]. There are three categories of fisheries resources of Bangladesh. These are inland capture, inland culture and marine capture. Marine fisheries contribution to food security and economic development of Bangladesh is extremely important and undeniable. In the coastal and exclusive economic zone (EEZ) of Bay of Bengal, 2.70 lac people are engaged in fishing (according to the report of Marine Fisheries Department). The verdict given by the International Tribunal for the Law of the Sea (ITLOS) and International Arbitration Tribunal over dispute of maritime boundary with Myanmar and India legitimately settles the EEZ (19,467sq.km) of Bangladesh up to 200 nautical miles from the baseline comprising 118,813 sq. km of maritime waters [5], [6]. All these areas of Bay of

Bengal offer potential sources especially white sea fishes and shrimp for the country. The contribution of marine fisheries has been continuously increasing over the years in Bangladesh. Due to the increased demand and high price of fishes both in domestic and export market, Bangladesh has great potentiality to gain huge foreign exchange by exporting marine fishes.

Bangladesh's geography in and around the Ganges Delta bordering the Himalayas to the north and the Bay of Bengal to the south makes it especially vulnerable to the impacts of climate change on coastal communities and the marine environment. Recent studies indicate a potential decrease in the marine fish catch due to climate change impacts [7]. Due to such impacts of climate change, sea fish supply chain in Bangladesh is facing a number of problems like long supply chain, production fluctuations, supply shortage, rough handling, inadequate transport and storage facilities, shortage of capital, market limitation etc. Thus, amongst all mentioned problems production fluctuations of sea fish has been obviously noticeable in last few years due to climate change impact. This research provides a holistic view of risk assessment and management of production fluctuations in sea fish supply chain. This research aims to analyze how production fluctuations of supply sea fish chain due to climate change could be effectively managed.

1.2 Problem Description

Bangladesh is particularly vulnerable to climate change in part due to its geography: the Ganges Delta, the world's largest river delta, comprises over half of Bangladesh's territory and its entire southern coast on the Bay of Bengal. Moreover, three of the world's largest rivers—the Ganges, the Brahmaputra, and the Meghna—drain their water and silt to the Bay of Bengal through Bangladesh. The Ganges-Brahmaputra (GB) delta is one of the most vulnerable deltas in the world due to the combined effect of glacier melt from Himalaya, extreme monsoon rainfall, sea level rise, land subsidence, storm surges and cyclones [8]. As a result, sea fish production is seriously hampered due to such frequent occurring climate change scenarios.

The main problem of sea fish supply chain is that there is no specific risk management framework to be followed to address this issue of production variations or fluctuations of sea fish due to climate change impacts. As a result, ultimately sea fish supply chain is failed to fulfill the growing customer demand of sea fish due to such fluctuations. Therefore, develop a risk management framework which can be applied in sea fish supply chain is very crucial to address the issue of production fluctuations due to deleterious effects of climate change in Bangladesh.

1.3 Objective of the Study

The objective of the Research "Risk management of production fluctuations in sea fish supply chain: A climate change perspective in Bangladesh" is as follow- to assess risks associated with production fluctuations in sea fish supply chain through proper risk management process from climate change perspective in Bangladesh.

1.4 Research Questions

Question 1: What are main reasons for productions fluctuations due to climate change in sea fish supply chain?

Question 2: How can production fluctuations in sea fish supply chain be addressed from a risk management viewpoint?

1.5 Research Structure

In this research, it has been designed into five steps. They are demonstrated below.

i. Literature review
ii. Research Methodology
iii. Findings and Analysis
iv. Discussion
v. Summary

In the first section of literature review, climate change impacts in the coastal area of Bangladesh have been analyzed through different various journals, brochures, annual reports, newspapers, publications etc. Since coastal area of Bangladesh is the main source of sea fish production and ultimately sea fish supply chain is badly affected by climate change events which has been proved in this following research sections by various sources of annual reports, journals, publications and newspaper sources and books etc. Finally, Supply chain risk management process has been explained in details through various journals, publications etc.

In the second section of research methodology in which a case study has been conducted to understand the details functions of sea fish supply chain and it helps to identify the vulnerable areas of supply chain that needs to be improved considering the impacts climate change. A qualitative approach has been used for the research, which includes survey to the selected location for detail study and in-depth interviews with related concerns through semi-structured questionnaires. Questionnaires for in-depth interviews is provided in Appendix.

In the third section of findings and analysis of risk management of sea fish supply chain considering the climate change impacts has been discussed which is the most significant part of the study. Already risk context has been analyzed in terms of case study section. After that risk identification, analysis and evaluation has conducted based on various sources of annual reports, journals, publications and newspaper sources and books etc.

In the fourth section which is discussed according to the evaluation, risk mitigation strategies have been identified and implementation strategies has been suggested. Finally, after implementation, risk control and monitoring will be conducted as a continuous iterative process.

At last, in the fifth and final section of summary, a new sea fish supply chain has been designed through flow chart based on risk mitigation strategies that will reduce the impact of production fluctuations due to climate change. Moreover, limitations are also discussed in this final section.

Chapter 2

Literature Review

2.1 Impact of Climate Change on Marine Resources of Bangladesh

Climate is the average weather conditions for a particular location over a long period of time, ranging from months to thousands or millions of years. World Metrological Organization (WMO) uses a 30-year period to determine the average climate [9]. According to united nations, Climate change refers to long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions [10].

According to sixth report of the Intergovernmental Panel on Climate Change (IPCC-AR6), ocean warming and ocean acidification have adversely affected food production from fisheries in some oceanic regions due to climate change. Future projected changes include further global mean sea level rise, include intensification of tropical cyclones and/or extratropical storms and increased ocean acidification and deoxygenation [2].

"Coastal zone" is most frequently defined as "land affected by its proximity to the sea and that part of the sea affected by its proximity to the land" or, in other words, the area where the processes which depend on the sea-land interaction are the most intensive. This interface is taking place along two axes: the axis running along the coast and the axis perpendicular to the coastline. The coastal zone of Bangladesh consists of 19 districts (see Figure 1 for Map of the coastal zone of Bangladesh) comprising 147 upazilas (administrative unit in Bangladesh) and the Exclusive Economic Zone (EEZ) [11].

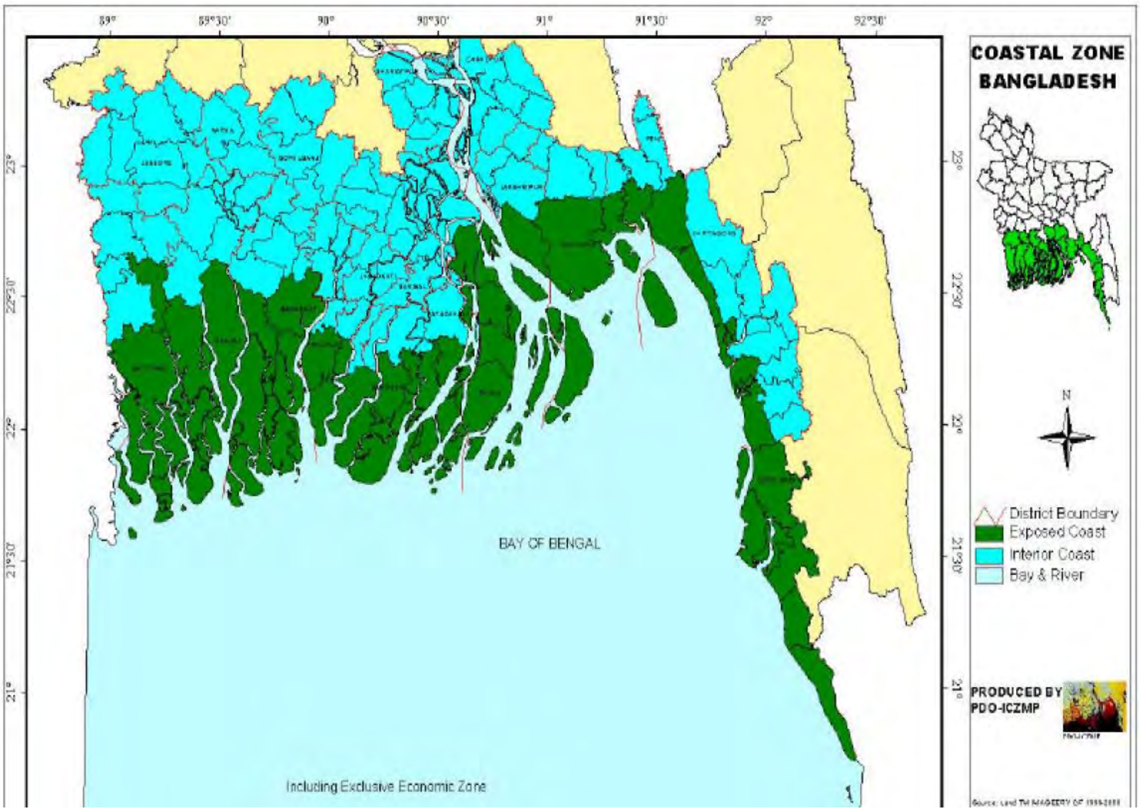

Figure 1: Map of Costal Zone of Bangladesh [11]

Bangladesh's coastal zone comprises nearly 50,000 square kilometers of marine waters rich in fish and other aquatic resources. These include the coral reefs and over 200 species of seaweed around Saint Martin Island, located off the southern tip of the Cox's Bazar peninsula [12]. The impacts of climate change on the ocean also threaten Bangladesh's living resources and marine life. Rising sea levels, extreme weather events, salinization of freshwater and soil, and ocean deoxygenation and acidification all threaten Bangladesh's biodiverse terrestrial and marine ecosystems. Bangladesh experiences different types of Natural Disasters almost every year because of the Global Warming as well as Climate Change impacts, these are mentioned in below Table 1 with their impacts on marine resources [13].

Climate change events	Impacts on marine resources
Warming/Rising Temperature	Coral belching, species migration, biodiversity loss, altered species lifestyle, disruption in marine food chain.
Cyclone	loss of coastal resources, degrade coastal habitats, loss of infrastructure facilities.
Sea level rise	Reduction in Photosynthesis of offshore plants and algae, disruption in mangrove ecosystem. This will lead to reduction in primary production and ultimately will affect the fisheries.
Costal Erosion	Clogging of air bladder of fish, mortality of the species, loss of coastal resources, degrade coastal habitats, loss of infrastructure facilities.
Coastal Floods / Tidal Surges	Loss of coastal resources, degrade coastal habitats, loss of infrastructure facilities.
Saline water intrusion	Crop damage, shift of species habitat
Flood	Crop damage, loss of infrastructures, loss of habitats.
Ocean acidification	Biodiversity loss, species migration, biodiversity loss, altered species life style, disruption in marine food chain.

Table 1: Climate Change impacts with their impacts on marine resources [13]

The cause-impact relationships of sea level rise and coastal fisheries of Bangladesh, as described in the following causal loop diagram or CLD in Figure 2, it has been depicted those coastal fisheries are affected by sea level rise in three ways; by salinity, by flooding and by increasing cyclone frequency and damage. These three factors collectively decrease the coastal fisheries [14]. So, decreased coastal fisheries causes protein scarcity, hinder foreign exchange and increase poverty.

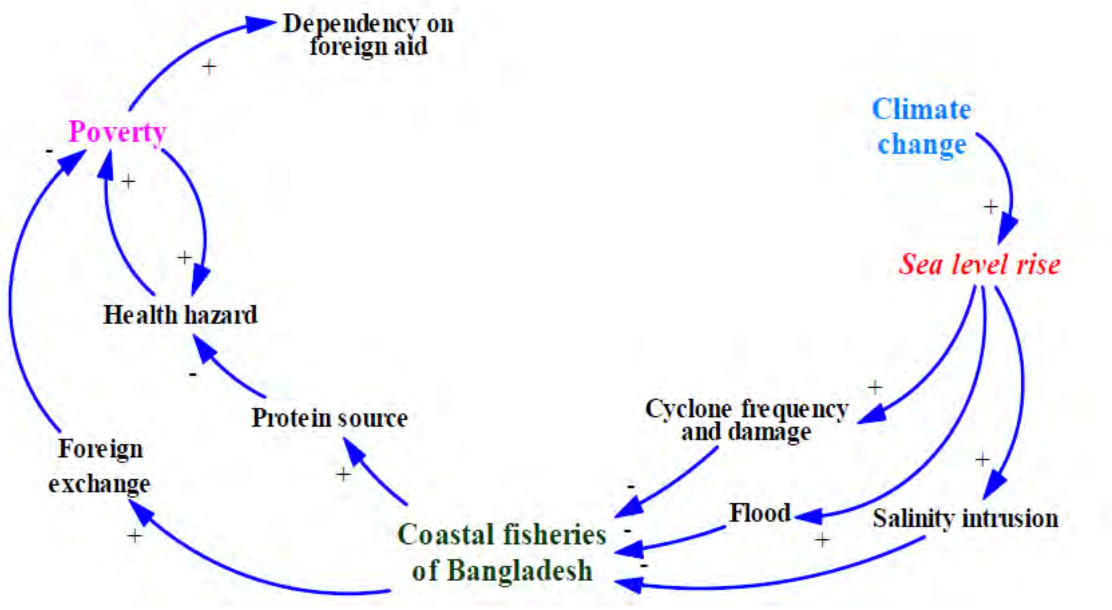

Figure 2: Causal Loop Diagram of sea level rise impacts on coastal fisheries sector [14]

2.2 Production of Marine Fisheries in Bangladesh

Marine Fisheries means fisheries out of the sea coastline. There are two types of fisheries in Bangladesh which are mentioned below:

1. Industrial Fisheries (Trawling): Fisheries using larger boats such as trawlers in marine waters fish beyond 40-meter water depth. Trawling is a method of that involves pulling Fishing net through the waters. Commercial fishing vessel having the high level of technology and investment designed to operate fishing trawlers for carrying out fishing on a large scale [4].
2. Artisanal Fisheries: Fisheries using relatively smaller boats. Artisanal fishing occurs in shallow water normally within 40-meter water depth using mechanical or non-mechanical boats. It refers to small-scale, low technology and low capital fishing practices undertaking by individual fishing households. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export. They are sometimes referred to as small-scale fisheries [4].

Marine fisheries are highly consumable commodity and its quality deteriorates very quickly. Production and consumption areas are also extensively separated. Since fish production in Bangladesh is increasing over the years, it throwing away pattern is very important as growers, wholesalers, retailers and consumers- all are affected due to value addition in the distribution process. In spite of contributing around 13.82% of the total fish of Bangladesh, still a lot of information is unknown to people about sea fishes [4]. In marine fishing involves over 232 industrial trawlers and more than 67669 artisanal vessels. Artisanal small-scale fishery contributes 78.50% i.e., that is 5.33 lakh MT and large-scale fishery contributes 21.50% i.e., that is 1.46 lakh MT of total marine production [4]. The historical data of marine fish production in year 2016-2023 according to department of fisheries has been depicted in below Table 2 [4].

Year	Total Industrial marine sea fish Production(kg)	Total Artisanal Marine Sea Fish Production(kg)	Total Annual Marine Fish Production(kg)	Total Annual Fish Production(kg)
2017-18	120087	534600	654687	4276641
2018-19	107236	552675	659911	4384221
2019-20	115354	555750	671104	4503371
2020-21	119121	562118	681239	4621228
2021-22	137170	568860	706030	4758731
2022-23	146037	533348	679385	4914715
Average	124167.5	551225.17	675392.67	4576484.50

Table 2: Marine fish production from 2016-2023 [4]

In Bangladesh, two types of trawlers are using to catch marine fish. One is Shrimp Fish trawlers which are engaged for catching shrimp. Another is White or fin Fish (other than shrimp) Trawlers. White Fish Trawlers are two types. One is Mid water trawler which are engaged for catching Pelagic fish (The fish live in the pelagic zone of sea being neither close to the bottom nor near the surface). Pelagic fishes are ranges from small sizes such as sardines, to large apex oceanic fishes, such as tuna and oceanic sharks. Another is Bottom trawler which are engaged for catching Demersal fish (These fishes live and feed on or near the bottom of seas). They occupy the sea beds, which usually consist of mud, sand, gravel or rocks. And 80% of the bottom trawlers are wooden hull. These wooden hull vessels have no freezing facilities. Modern navigation system, standard safety equipment and modern fishing technology & methods are totally absent in these types of fishing trawlers [15].

2.3 Proactive Supply Chain Risk Management (PSCRM)

Risk is an effect of uncertainty on objectives. An effect is a deviation from the expected. ISO 31000 (2018) is a family of standards relating to risk management codified by the International Organization for Standardization. The purpose of this standard is to provide principles and generic guidelines on risk management. According to ISO 31000 (2018), risk can be positive, negative or both, and can address, create or result in opportunities and threats. Risk can be divided into different categories [16].

- Known Risks: These are risks that are measurable and can be planned for. Known risks, also called hard risks, include process breakdowns, poor material, poor quality control, criminal activity, poor and unreliable systems, and failure of a company's facilities and assets. The critical issue with known risks is that without addressing them with permanent solutions, an organization tends to be plagued with these risks daily to the point where they lose visibility, confidence, and commitment, leading to a potential major internal disruption. This breakdown within a company's processes can be as impactful as a catastrophic event emanating externally [17].

- Unknown risks: These risks are difficult to determine and are sometimes called soft risks. Risks within this category could be political, weather and acts of God, fraud, corruption, counterfeiting, and competition. The bulk of these risks is mitigated and managed through the use of scenario-based planning approaches, be it at a specific facility level or throughout an entire supply chain network. Most of the unknown or soft risks in this category can and should be planned for using scenario-based BCP or risk response plans. Historically, almost every soft risk is event-driven in nature. When these soft risks emerge, whether inside or outside a company, organizations should address the issue as quickly as possible. The bottom line in this area of risk is that it will continue to grow in terms of scope and scale as long as companies continue to penetrate new global markets. The approaches to manage these risks will also continue to emerge and perhaps migrate from reactive to more proactive in nature [17].

According to Sunil Chopra "supply chain consists of all parties involved directly or indirectly in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves." [18]. According to W. J. Stevenson "supply chain is a sequence of organization, their facilities, function and activities that involved in producing and delivering a product or service." [19]. Steps of Supply Chain has been depicted in below Figure 3. The definition of supply chain management according to Martin Christopher "the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole." [20].

Figure 3: Steps of Supply Chain [18]

There are risks in the supply chain when unexpected events might disrupt the flow of materials on their journey from initial suppliers through to final customers. An initial definition of supply chain risk is encompassed by Waters as "supply chain risk appears as any event that might affect this movement and disrupt the planned flow of materials." [21] . Zsidisin defines supply chain risk as "the potential occurrence of an incident or failure to seize opportunities with inbound supply in which its outcomes result in a financial loss for the purchasing firm." [22]. SCRM is the implementation of strategies to manage every day and exceptional risks along the supply chain through continuous risk assessment with the objective of reducing vulnerability and ensuring continuity. One way to view supply chain risk management is to think of it as the intersection of supply chain management and risk management [23]. Juttner suggest that supply chain risk management is the process of identifying and managing risks in the supply chain through a coordinated approach amongst supply chain members in order to achieve the supply chain objectives [24].

Supply chain risk management strategies can be described as being reactive or proactive. Being reactive is a default position when a risk materializes. This is in effect necessary when a supply chain operates without worrying about risks on a day-to-day basis but reacts to mitigate when the difficulty or disruption strikes. This impacts the supply chain members until the situation is resolved, which needs to be done quickly as a delay can cause serious damage [25]. To overcome the need to react after the occurrence of an event, a proactive strategy has been proposed by researchers [26]. The focus of this exercise is to target the identified risks in order to avoid them. This may not be possible in all cases and hence there is a need to develop and implement contingency plans to minimize the impact if and when the risk occurs [25].

2.4 Supply Chain Risk Management (SCRM) Process

A systematic risk management process usually comprises the stages of (1) risk identification, (2) risk analysis (including risk assessment and classification), (3) risk management in the narrow sense, e.g., risk treatment, and (4) risk monitoring. The overall objective of this process is to determine, implement, and monitor an optimal mix of measures to avoid, defer, reduce, or transfer all relevant risks. This generic risk management process was transferred and adapted to the supply chain context by various authors [27].

Based on the proactive approach, a supply chain risk management process is adopted from ISO 31000 (2018) recommended risk management process which is depicted in below Figure 4 and different phases has been described according to supply chain risk management process [16].

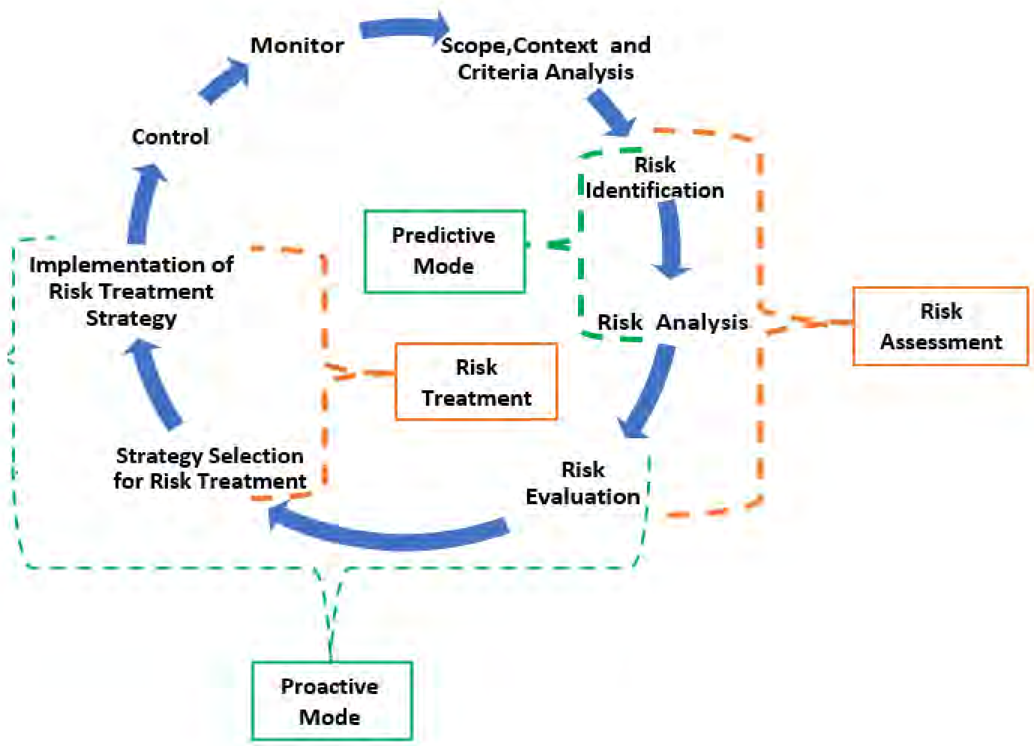

Figure 4: Steps of Supply Chain Risk Management adopted from ISO 31000:2018 [16]

1) Phase One: Scope, Context and Criteria Analysis

Context analysis consists of the definition of the issue to be managed. From the context analysis, the scope of the risk management process can be developed, delimiting members that should be taken under consideration and their responsibilities within the supply chain [28]. Supply chain mapping is one of the tools applied for context analysis has been demonstrated below.

- Supply chain mapping – The most cited tools for the context analysis phase are supply chain mapping [28], [29] and interviews [30], [31]. A supply chain map is a graphical representation of a firm's tier-one and sub tier suppliers for any purchased item, whether it is a finished product, system or assembly, or component. Better maps will also include the downstream portion of the supply chain [32] .

2) Phase Two: Risk Identification

During the risk identification, the risks to which the selected members of the chain are exposed to are identified. The risk identification phase is considered the main phase in the process of supply chain risk management by many authors [28], [33], [34]. Tools can be applied to identify supply chain risk are demonstrated below.

- Expert opinion- People with experience in different areas are considered as expert and supply chain experts have lots of knowledge of risks and their opinion are crucial for risk identification [35], [36].
- Literature Review- It is one of the major tools suggested for risk identification phase [35], [36].

- Brainstorming- It is one of the major tools suggested for risk identification phase [28]. Brainstorming is a creative thinking technique for coming up with new ideas and solving problems.
- Historical data/problems- Historical problems may have a high chance of recurring. Use of historical data to see how often one event has happened in the past and predict its probability for the future [37].
- Site visits – Site visits to supply chain partners allow you to collect detailed and less "filtered" information on risks [38].

3) Phase Three: Risk Analysis

Risk analysis is the process in which risks are examined at various degrees of detail to determine the extent of the risks, how risk elements are related to each other, and which ones are the most important to deal with [39]. Some specific tools are applied for risk analysis are demonstrated below.

- Pareto chart- A frequency diagram of risky events that actually occurred in the past can suggest those that are more likely to reoccur in the future. Pareto charts are based on the observation that 80 per cent of risks come from 20 per cent of causes [40]. The Pareto principle also known as the 80/20 rule, the law of the vital few and the principle of factor sparsity states that for many outcomes, roughly 80% of consequences come from 20% of causes (the "vital few") [41].
- Linear regression- Linear regression is a versatile analysis. Simple linear regression shows the relationship between a dependent variable and an independent variable. A useful function of linear regression is to predict values of the dependent variable; though such prediction does not imply causation. Linear

regression is available for a number of quantitative methods, including cross-sectional surveys, longitudinal surveys, and experimental designs [42].

4) Phase four: Risk Evaluation

The risk evaluation phase consists of estimating the risk event's occurrence probability and potential impacts and, therefore, prioritize risks that affect chain vulnerability [28], [33], [34]. One of the tools for risk evaluation has been explained below.

- Correlation- Correlational analysis in interval/ratio variables prerequisites confirming a linear relationship and no outlier in the data using Scatterplots. It suggests a positive linear relationship between two variables, where as one variable increases, another also increases. It suggests a negative linear relationship, where as one variable increases, but another decreases. Besides this, it also shows that the points on the graph are scattered randomly and depicts no apparent linear relationship. The most familiar measure of dependence between two quantities is the "Spearman's correlation coefficient correlation coefficient", commonly called simply "the correlation coefficient". Spearman's correlation coefficient is a measure of correlation which uses rank order to determine the magnitude and direction of relationship between two sets of ranked data [43]. It is obtained by taking the ratio of the covariance of the two variables in question of numerical dataset, normalized to the square root of their variances. Mathematically, one simply divides the covariance of the two variables by the product of their standard deviations. The values for Spearman's correlation coefficient vary between −1.00 and +1.00. The correlation coefficient is defined as

$$Rxy = \frac{\sum_{i=1}^{n}(x\mathrm{i}-\bar{x})(y\mathrm{i}-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x\mathrm{i}-\bar{x})^{2}\sum_{i=1}^{n}(y\mathrm{i}-\bar{y})^{2}}} \qquad (1)$$

Rxy – the correlation coefficient of the linear relationship between the variables x and y

x_i – the values of the x-variable in a sample

$\bar{x}$ – the mean of the values of the x-variable

y_i – the values of the y-variable in a sample

$\bar{y}$ – the mean of the values of the y-variable

5) Phase five: Strategy Selection for Risk Treatment

The selection of a risk mitigation strategy consists in evaluating various possible strategies in order to select the one that best suits each risk's treatment [28], [33], [34]. Several risk treatment options are discussed below.

i. Risk Avoidance: Avoidance involves exiting those activities that give rise to a risk. A company may decide (and many have) that sourcing a material from a certain supplier is too risky, so it avoids that supplier. Or, a certain line of products is not earning enough profit, so a company decides to stop making those items [23] .

ii. Risk Prevention**:** Prevention involves taking action to ensure that a risk does not become a risk event or, if it does become an event, that it will have an inconsequential effect. This approach to managing risk is often preferable when dealing with known risks. Prevention is different from avoidance in that a company did not exit something as a means of addressing risk [23].

iii. Risk Acceptance**:** Acceptance means to take on and assume a risk. SCRM may not be a priority, so therefore no specific risk management action is taken. In this case acceptance occurs essentially by default. A second reason for risk acceptance is that a cost/benefit analysis reveals that the cost of addressing a risk outweighs the expected impact of the risk. A third reason is that no practical way exists to prevent, share, or mitigate the risk [23].

iv. Risk Mitigation: According to its most basic definition, mitigate means to lessen the impact of something. In a broader sense, mitigation can also be the result of action taken to either reduce the likelihood of a risk occurring or minimize the extent of its impact. This broader perspective is why many sources refer to just about any risk management initiative as risk mitigation. Mitigation or risk responsiveness is essential when unknown risks are present. Not everything can be anticipated or prevented [23].

v. Risk Sharing: Risk sharing involves transferring or sharing a portion of a risk to reduce or mitigate it. Risk pooling is an important form of risk sharing. A risk pool involves insurance companies controlling the risk of insuring against catastrophic events or extending insurance to individuals or businesses that are likely to create sizable claims. If a claim arises from a natural disaster or catastrophic weather event, the companies spread losses among all members of the risk pool. Single members of the risk pool are protected from large claims that would bankrupt the insurance company, leaving their claimants with nothing [23] .

6) Phase six: Strategy Implementation

During the risk treatment strategy implementation phase, the selected strategy is implemented focusing on treating the previously prioritized risk [28], [33], [34]. This phase may treat the cause (probability reduction) as well as consequence (impact reduction) [28], [34]. After the selected strategy is implemented, it must also be controlled, verifying its efficiency with respect to the prioritized and treated risk.

7) Phase seven: Control

Therefore, the control phase's purpose is to evaluate the progress obtained through the implemented strategy and establish possible corrective actions in case there are any deviations and/or the strategy does not fulfill the expected goal [28], [34]. Because the supply chain's structure and operations change regularly, new risks may emerge; confirming the importance of the monitoring phase [34]. It is worth noting that during the control phase, the strategy is evaluated in regard to its result before the risk to be treated.

8) Phase Eight: Monitor

Monitoring consists of supervising the chain in order to detect new risks, identify tendencies, probabilities and impacts [28], [33], [34]. In the monitoring phase, behavior and tendencies are observed, with the purpose of anticipating new risks. Real time metrics and periodic reports give decisions maker's knowledge upcoming risks. Statistical analysis of key metrics can reveal trends. Visibility into supplier and customer metrics increases the ability to monitor [38].

Chapter 3

Research Methodology

This chapter contains the details of research methodology which has been divided into five sections and findings of case study. Five sections of research methodology are demonstrated below.

1) Research design

The research design is based on two research question; this first prime requirement is to identify the reasons behind production fluctuations in sea fish supply chain due to climate change impacts. So, production data and various climate change impact data are required to address the first question which follows the descriptive research design. Finally in the second question, in which way identified risks can be solved from risk management viewpoint have to be addressed. Therefore, a case study has been conducted to understand the sea fish supply chain in a sea fish producing organization by recommending solution guidelines according to risk management view point which follows the exploratory research design.

The research work follows both quantitative method and qualitative method that means mixed method. Mixed-method research methodology uses the characteristics of both quantitative and qualitative research methodologies in the same study. This method has been chosen for below reasons.

- Firstly, in the quantitative method to answer the first question, various production and climate change data from different sources have been analyzed through descriptive analysis such as frequency measures, regression and correlational analysis.
- Secondly, in the qualitative method to answer the second question, to verify and evaluate the results from descriptive analysis, important themes or patterns have been

identified and analyzed in the case study data which helps to address production fluctuations in sea fish supply chain from a risk management viewpoint.

2) Case Selection

The Sea Resources Ltd which is a sister concern of Sea Resources Group (SRG) is considered for this research. This organization is selected for the study and their respective characteristics are listed in Table 3.

Characteristics	Sea Resources Group (SRG)
Duration	It was founded in 1982 and pioneer of the business of deep-sea fishing in Bangladesh.
Vision	To establish the deep-sea fishing sector in Bangladesh
Market Growth	Top of becoming the leader in the local market as well as in the export market as well.
Business Diversification	Sea Fishers Limited trawlers are engaged in both shrimp and white fish trawling from the Bay of Bengal and the products of these trawlers are mostly exported and also sold in local market.
Trawlers Facility	Trawlers are equipped with on board processing and freezing.
Storage Capacity	Cold storage facilities with ~2,000 MT capacity.
Quality assurance	No preservative is used during storage by maintaining excellent quality standard.

Table 3: Characteristics of Sea Recourses Group

3) Study Location and Geography

The research has been conducted in Cox's Bazar's fishery ghat, a wholesale market for marine fish, which is located on the bank of Bakkhali River next to Cox's Bazar Airport. Cox's Bazar Fishery Ghat is the biggest destination for sea fish in Cox's Bazar, Bangladesh. Core economic activities in the region are based on sea fishing. Figure 5 shows the map mentioning the study locations.

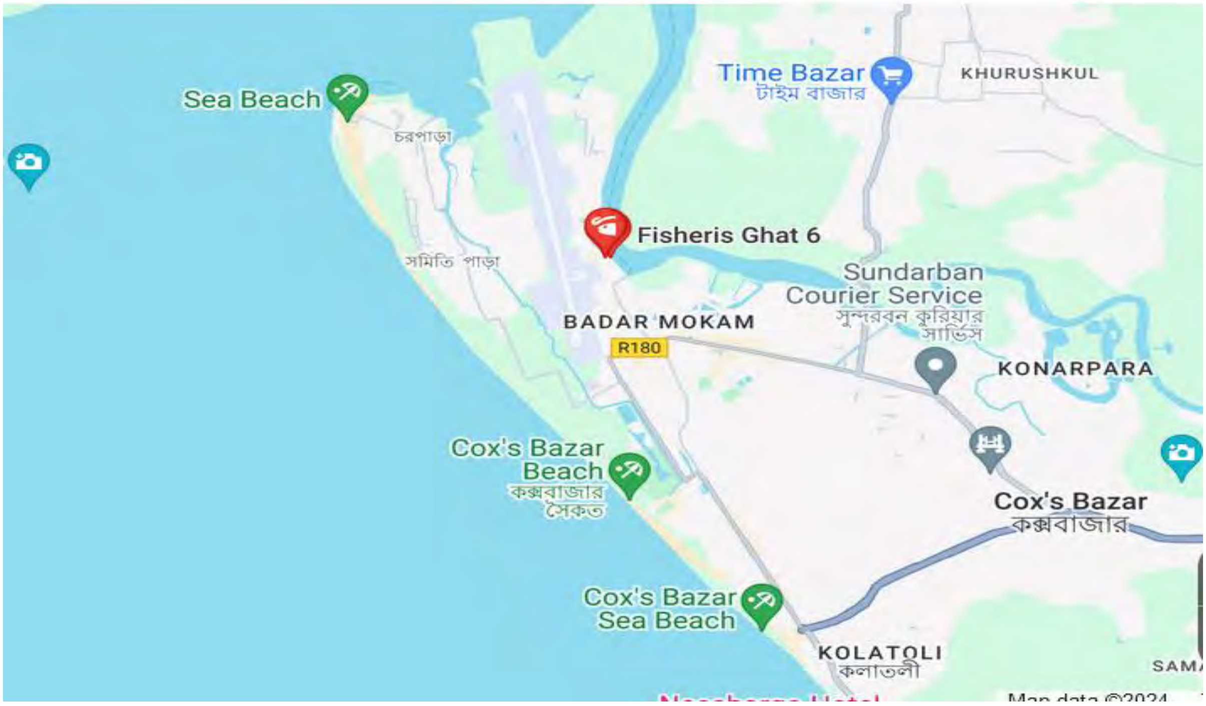

Figure 5: Map of Study Location

4) Sample Size and Profile of Respondents

This study selected 20 respondents for in-depth interview from different sources as mentioned in Table 4.

Profession/organization of respondent for interview	**Number of respondents**
Fishermen	5
Agents	3
Government officials	1
Wholesalers	2
Cold storage Concern	2
Vessel Crew	3
Company Officials	2
Trawler Owner	2
Total	20

Table 4: Profile of the respondents for in-depth interview

5) Data Collection

At first climate change impacts in Bangladesh is discussed as below mentioned primary sources to collect required data for analysis and a final case study was conducted to have detailed information about supply chain of marine or sea fish in industrial fishing trawler company and data have been collected through detailed in-depth interviews to assess climate change impacts in industrial sea fish supply chain. However, data were collected both primary and secondary sources.

- Primary Sources: Primary sources of data specially climate change impacts and supply chain risk management details are collected from various journals, brochures, annual reports, newspapers, magazines, publications, books, and other forms of publications as well as websites from government organizations.
- Secondary Sources: Secondary data regarding the case study are collected by both in-depth interview through face-to-face communication with concern

bodies, government authorities, vessel crew, wholesaler or Fish party and discuss with them about the capturing, processing, freezing, storing, tendering, unloading, transporting and selling of fishes.

6) Data Analysis

There are many tools and techniques available to assess climate change data analysis. Based on ISO 31000 (2018) different analysis has been performed through different tools and techniques and they are historical data analysis, Pareto analysis, linear regression analysis etc. [16] . During analysis data were generalized related to the core research questions this research intends to answer; and later categorization, abstraction and comparison were performed to compartmentalize the information according to the two research questions.

3.1 Phase One: Case study for Context Analysis

For context analysis, developing and understanding sea fish supply chain network is very crucial. This study is conducted to determine the supply chain and distribution network. That's why The Sea Resources Ltd which is a sister concern of Sea Resources Group (SRG) is considered for this research from the context of industrial fisheries. Generally, in this case, industrial fisheries have been considered and analyzed deeply since the sea fish supply chain of concern organization is operated through industrial fisheries. According to above mentioned research methodology, case selection is based on Table 3 and below findings are identified based on geographical study location and secondary sources of data collection.

- Findings of Sea Fish Supply Chain Network

In this research, after visiting the factory and operation sites at different places and consulting with related concerns through questionaries which has been mentioned in Appendix section and findings of sea fish supply chain network have been explained in details this section. Findings of sea fish supply chain network has been divided into three categories. They are explained below.

1) Supply Chain Operation:

Normally a mid-water trawler gets the sailing permission **(**issued by Marine Fisheries Department) for 30 days. A mid water trawler trawling duration normally 4 hours or less. When hauling completed that means catch on the deck, crews started to sorting the fish according to their species and sizes. Then properly wash the fish. After that, packing the fishes according to their species and sizes. Normally a packet (called fish block) contains 20 to 25 kilograms fish. When packing completed, store the fish into the fish hold (hatch) for freezing. After that when freezing temperature reach at -25° centigrade to -35° centigrade, then separate the frozen fish packet for final storing. This freezing process normally takes 36 to 48 hours. This period varies freezing compressor performance and species of fishes. This is a continuous process and it is going on until completing the voyage. Sea fish is marketed both domestically and globally.

2) Supply Chain Intermediaries

A short description of supply chain intermediaries of fishing trawler has described below.

a) Wholesaler or Main or 1st Fish Party: They are the first intermediaries or channels after owner of supply chain of marine fish. After completing a voyage, when a fishing trawler comes at harbor, vessel Skipper gives a catch report to the office. Then office management sends the message to the enlisted parties of the company and arrange a tender for selling the fish. The Fish party only who has deposited security money to the office can attend the tender. Normally 5 to 10 parties attend the tender. The party who gives the maximum rate, get the tender. This rate of fish is variable. Different types of fish have different rates on different time. Fish party gives the rate by justifying the daily market rate. They buy the large volume of fish from a trawler. After getting the proprietary right, they started to unload the fish through the trawler. These boats are the special boat which engaged only unloading the fish and these boats can carry 10 to 15 tons of fish. Then they store the fish at the cold storage.

b) Cold Storage: After unloading the fish from the vessel, normally the first or second fish party store the fish at the cold storage. The first or second fish party uses the cold storage as distribution center. The party who are engaged for exporting fish to abroad, they first store specific fish at the cold storage until their desired volume. After ensuring the clearance of quality controller, these fishes are directly sends to the port for exporting.

c) Agent or Broker: Agent or broker is a commission agent who has a fixed establishment and helps the 1st or 2nd fish party to sell their fishes. They hire labors and other persons for performing various functions such as loading, unloading, weighing, grading, etc.

d) Retailer: They buy fish from the first fish party and 2nd fish party through agents or brokers. They sell their fish to the consumer at various local markets.

e) Consumer: This is the last stage of the supply chain system of marine fish. Consumers buy the fish from the retailer. Due to this long supply chain, consumers are getting the product at a higher price with delay delivery.

3) Types of Sea Fish Supply Chain Network

There are three types of sea fish supply chain network has been identified in following case study. They are:

i. Shrimp Supply chain network (Direct Export): Fishing trawler owner specially shrimp trawler, and fish party or wholesaler whose have exporting license, only they can export these fish to abroad. It's the simplest form of fish supply network which has been depicted in Figure 6.

Figure 6: Shrimp Supply chain network (Direct Export through wholesaler)

ii. Sea Fish Supply chain network (Export through wholesaler): In this network, after unloading these fish from the trawler, trawler owner or fish party store these fish at cold storage until their desired volume. After getting the clearance or certify by the quality controller, trawler owner or fish party send their required volume of fish to port for exporting. Finally, fish is exported from cold storage and following supply chain has been depicted in Figure 7.

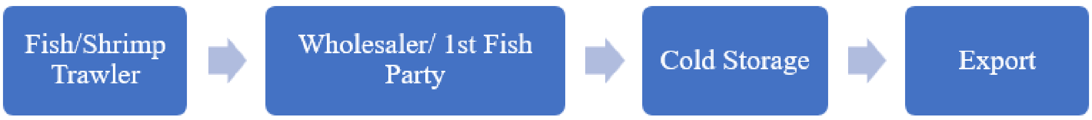

Figure 7: Sea Fish Supply chain network (Export through wholesaler)

iii. Sea Fish Supply chain network for domestic market (Wholesaler to Consumer): In this network, fish supply is started from fish trawler or owner to final consumer for domestic market. There are several subsequent intermediaries between fish trawler or owner and consumer. Following intermediaries are wholesaler, cold storage, agent and retailer depicted in Figure 8. This network is more complex than direct export network.

Figure 8: Sea Fish Supply chain network for domestic market

(Wholesaler to Consumer)

Among above mentioned supply chain network, Sea Fish Supply chain network for domestic market (Wholesalers to Consumers with intermediaries) is the most complex type of network which is selected for risk management due to its additional intermediaries regarding climate change impact in Bangladesh.

Chapter 4

Findings and Analysis

This chapter contains findings and analysis which has been done to answer the main reasons for productions fluctuations due to climate change in sea fish supply chain. For which data has been collected from government and private organizations, publications, journals etc. This chapter is divided into three phases of according to supply chain risk management process. They are risk identification, analysis and evaluation which has been explained below sections. In each phase of risk management data presentation, detailed analysis and key findings are identified and explained accordingly.

4.1 Phase Two: Risk Identification Regarding Climate Change

- Introduction

In this second phase of risk identification, data has been collected from primary sources as per mentioned in research methodology section. Literature review and historical data have been analyzed to identify the risks due to climate change in sea fish supply chain with proper justification of information sources according to research methodology.

- Presentation of data

According to Bangladesh Bureau of Statistics, historical data of loss and damage caused by natural disasters from the year 2015-2020 has been presented in below Table 5 and damage and loss by type of disaster from the year 2015-2020 have been presented in below Table 6 [44].

Sector Wise Damage and Loss	Sector Wise Damage and Loss (In Million TK.)	Percentage (%) /Average
Crops	517961	28.90
Livestock	71373	3.98
Poultry	26976	1.51
Fishery	66460	3.71
Land Degradation	941843	52.56
Dwelling & Others Infrastructures	132315	7.38
Homestead Forestry	35061	1.96
Total	1791988	

Table 5: Sector Wise Damage and Loss [44]

Damage and Loss by Disaster	Damage and Loss by Type of Disaster (In Million TK.)	Percentage (%) /Average
Drought	27334	1.53
Flood	1010882	56.41
Water logging	93860	5.24
Cyclone	255382	14.25
Tornado	15226	0.85
Storm/ Tidal surge	15475	0.86
Thunderstorm	29195	1.63
River/ Coastal erosion	268703	14.99
Landslide	6082	0.34
Salinity	20756	1.16

Hailstorm	48945	2.73
Others	136	0.01
Total	1791988	100

Table 6: Damage and Loss by Type of Disaster [44]

- Description of key findings

From above Table 5 it has been concluded that loss and damage amount in fisheries sector due to climate change impacts caused natural disasters is almost 66460 million takas from the year 2015-2020. So, the industrial marine fisheries sector has been also affected due to climate change impacts. From above Table 6 it has been concluded that major loss and damage caused by various natural disasters in Bangladesh from the year 2015-2020 has been mentioned below [44].

i. Flood
ii. Cyclone
iii. Water logging
iv. River/coastal erosion

Climate change impacts with their impacts on marine resources has been already mentioned in Table 1 of literature review. They are

i. Flood
ii. Cyclone
iii. Sea level rise
iv. River/coastal erosion
v. Warming/Rising Temperature
vi. Ocean acidification

vii. Salinity intrusion

From Figure 2 in literature review, three main sources of sea level rise are identified and which are mentioned below.

i. Cyclone frequency
ii. Flood
iii. Salinity intrusion

- Summary of findings.

From above key findings, below risks are identified due to climate change impacts in Bangladesh by analysis of literature review and historical data.

a. Flood
b. Cyclone
c. Water logging
d. River/coastal erosion
e. Salinity intrusion
f. Warming/Rising Temperature
g. Ocean acidification

4.2 Phase Three: Analysis of Identified Risks

- Introduction

In this third phase, further detailed analysis has been conducted for such identified risks such as such as flood, water logging, cyclone, river/coastal erosion etc. to determine the extent of risks and which one is the most important to deal with. In this phase of risk analysis, data has been collected from various primary sources as per mentioned in research methodology section.

Different tools such as pareto analysis and linear regression have been applied to analyze the identified risks according to research methodology and they are demonstrated below.

- Presentation of data

According to Bangladesh Bureau of Statistics, historical data of loss and damage distribution of fisheries sector according to disaster type from the year 2015-2020 has been presented in below Table 7 [44] .

Damage and Loss by Type of Disaster	Damage and Loss by Type of Disaster (In Million TK.)	Percentage (%) /Average
Drought	262	0.394
Flood	40927	61.581
Water logging	6281	9.451
Cyclone	11542	17.367
Tornado	165	0.248
Storm/ Tidal surge	2117	3.185
Thunderstorm	232	0.349
River/ Coastal erosion	2498	3.759
Landslide	1	0.002
Salinity	2216	3.334
Hailstorm	214	0.322
Others	5	0.007
Total	66460	100

Table 7: Loss and damage distribution of Fisheries sector according to disaster type from the year 2015-2020 [44]

The historical data of industrial marine fish production in year 2017-2023 according to department of fisheries has been depicted in below Table 8 [4].

Year	Total Industrial marine sea fish Production(kg)	Total Annual Fish Production(kg)	Percentage share (%) of Industrial Sea Fish
2017-18	120087	4276641	2.81%
2018-19	107236	4384221	2.45%
2019-20	115354	4503371	2.56%
2020-21	119121	4621228	2.58%
2021-22	137170	4758731	2.88%
2022-23	146037	4914715	2.97%
Average	124167.5	4576484.50	2.71%

Table 8: Industrial Marine fish production from 2017-2023 [4]

The historical data of Major Cyclonic Storms from 2001 to 2023 according to Bangladesh Metrological Department is depicted in below Table 9 [44].

Year	Date of Occurrence	Nature of Phenomenon	Landfall Area	Maximum Wind Speed in km/hr	Total No of Cyclone Occurrence
2002	12.11.2002	Cyclonic Storm	Sundarban Coast near Raimangal River	65-95	1

2004	19.05.2004	Cyclonic Storm	Teknaf-Akyab Coast	65-90	1
2007	14.05.2007	Severe Cyclonic Storm (AKASH)	Chittagong Coast	120	2
	15.11.2007	Severe Cyclonic Storm with core of hurricane winds (SIDR)	Khulna-Barisal Coast near Baleshwar River	223	
2008	26.10.2008	Cyclonic Storm (RSHMI)	Barisal Coast	85	1
2009	19.04.2009	Cyclonic Storm (BIJLI)	Chittagong Coast	55	2
	25.05.2009	Cyclonic Storm (AILA)	West Bengal-Khulna Coast near Sagar Island	70-90	

2013	16.05.2013	Cyclonic Storm (MAHASEN)	Noakhali-Chittagong Coast	100	1
2015	30.07.2015	Cyclonic Storm (KOMEN)	Chittagong-Cox's Bazar Coast	65	1
2016	21.05.2016	Very Severe Cyclonic Storm (ROANU)	Barisal-Chittagong Coast near Patenga	128	1
2017	30.05.2017	Very Severe Cyclonic Storm (MORA)	Chittagong-Cox's Bazar Coast near Kutubdia	146	1
2019	04.05.2019	Severe Cyclonic Storm (FANI)	Odisha Coast of India, then moved towards Bangladesh	81	2
	09.11.2019	Severe Cyclonic Storm (BULBUL)	Sagar Island of India, then moved towards Bangladesh	91	

2020	20.05.2020	Severe Cyclonic Storm (AMPHAN)	West Bengal-Bangladesh Coast	160	2
	26.05.2021	Very Severe Cyclonic Storm (YAAS)	Northern India-Chittagong-Cox's Bazar Coast - Noakhali-Khulna Coast	140	
2022	24.10.2022	Cyclonic Storm (SITRANG)	Barishal-Chattogram Coast near Bhola	88	1
2023	14.05.2023	Very Severe Cyclonic Storm (MOCHA)	Crossed Cox's Bazar-North Myanmar Coast near Sittwe and the area of Myanmar	120-130	1

Table 9: List of Major Cyclonic Storms from 2001 to 2023 [44]

The historical data of Flood Affected Area(sq-km) from 2001-2023 according to Bangladesh water Development Board is depicted in below Table 10 [4].

Year	Flood Affected Area(sq-km)	Flood Affected Area (%)
2001	4000	2.8
2002	15000	10
2003	21500	14
2004	55000	38
2005	17850	12
2006	16175	11
2007	62300	42
2008	33655	23
2009	28593	19
2010	26530	18
2011	29800	20
2012	17700	12
2013	15650	10.6
2014	36895	25
2015	47200	32
2016	48675	33
2017	61979	42
2018	33941	23
2019	45747	31
2020	59028	40
2021	48698	33
2022	39991	27.1

2023	37925	25.7
Average	33860.9	22.92

Table 10: Year-wise Flood Affected Area in Bangladesh [44]

- Detailed analysis

Although several sources of risks due to climate change impact has been identified in risk identification phase. But it's very much necessary to identify the most important ones to deal with such types of natural disasters. For this reason, pareto analysis has been carried for further detailed analysis of the historical data mentioned in Table 7 [44].

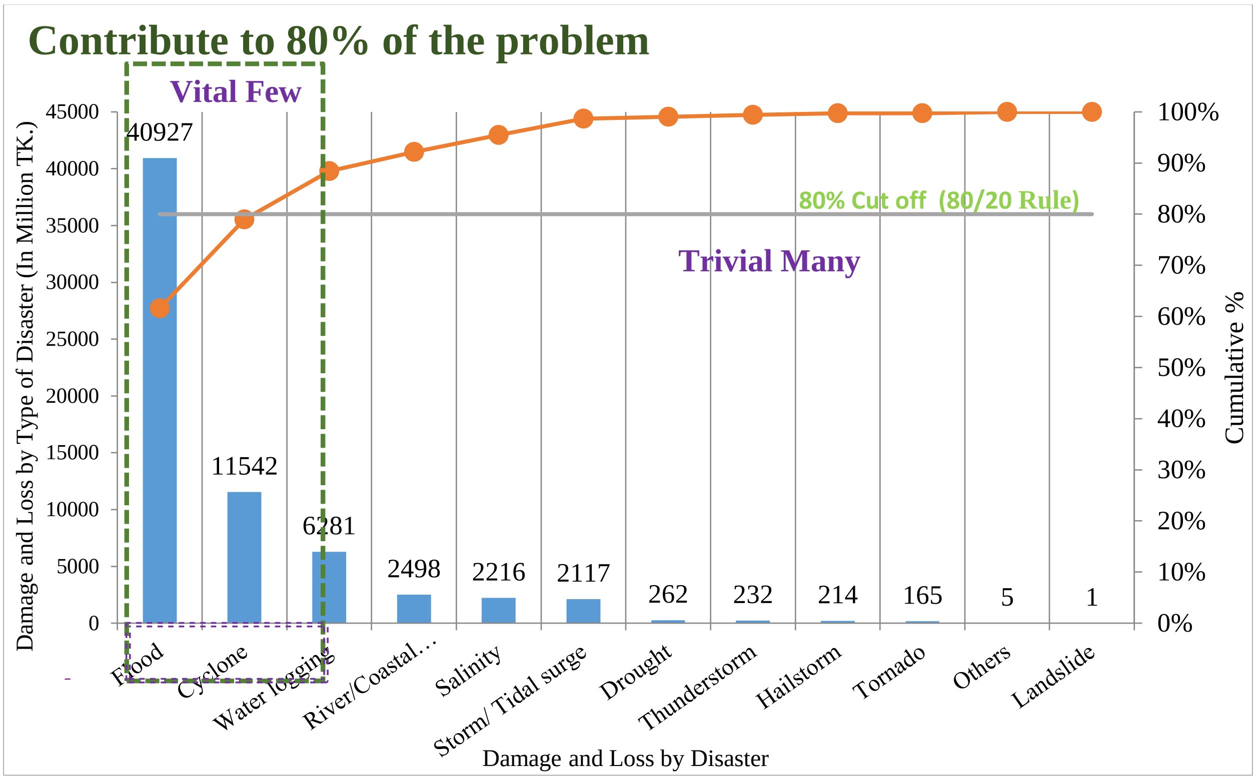

Figure 9: Pareto Analysis of Damage and Loss of Fisheries sector by Disaster

According to above pareto analysis in Figure 9 by analyzing the data from Table 7, almost 78.95 % which vital few of the loss and damage of Fisheries sector caused by flood and cyclone in fisheries sector from the year 2015-2020 and total damage and Loss (In Million TK.) due to for both cyclone and flood which is 52469 million takas.

From Table 8 it has been also calculated that approximate industrial marine fish production is almost 2.99% share in whole fisheries sector from the year 2015-2020. Therefore, Damage and Loss caused by Flood and Cyclone (In Million TK.) in Industrial marine Fisheries Sector (Approximately)

= Damage and Loss caused by Flood and Cyclone (In Million TK.) in Fisheries Sector X Average Production Percentage share (%) of Industrial Marine Fisheries

= 52469 million takas x 2.99 % = 1568.82 million takas

Finally, loss and damage caused by flood and cyclone in industrial marine fisheries sector is approximately 1568.82 million takas from the year 2015-2020 in Bangladesh.

- Statistical analysis

According to data cyclone occurrences in each year from 2001-2023 in Table 9, linear forecast trend of cyclone occurrences in upcoming years has been analyzed through excel linear regression which depicted in below Figure 10.

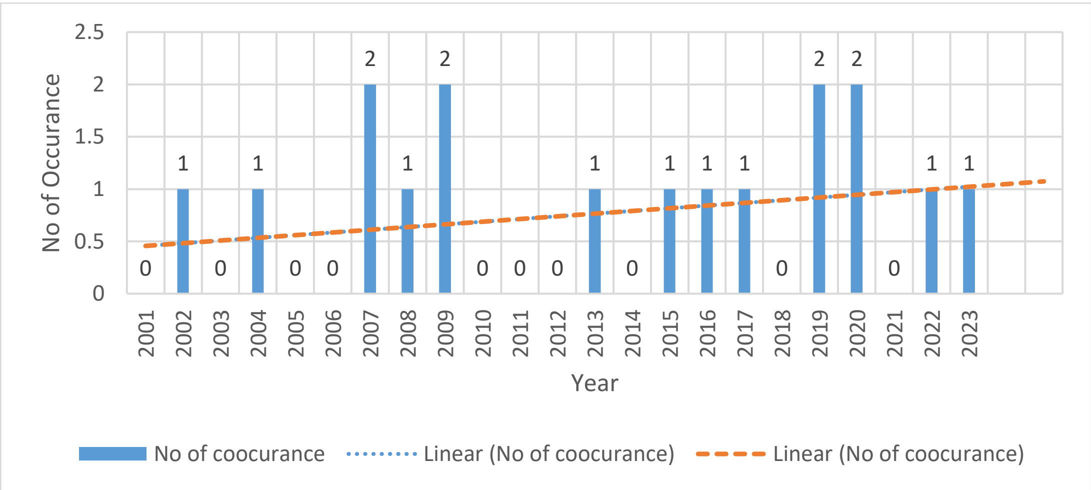

Figure 10: Linear regression analysis of cyclone occurrences from year 2001-2023

According to data of flood affected area in each year from 2001-2023 in Table 10, from which linear forecast trend of flood affected area in upcoming years has been depicted in below Figure 11 which has been analyzed through Excel linear regression.

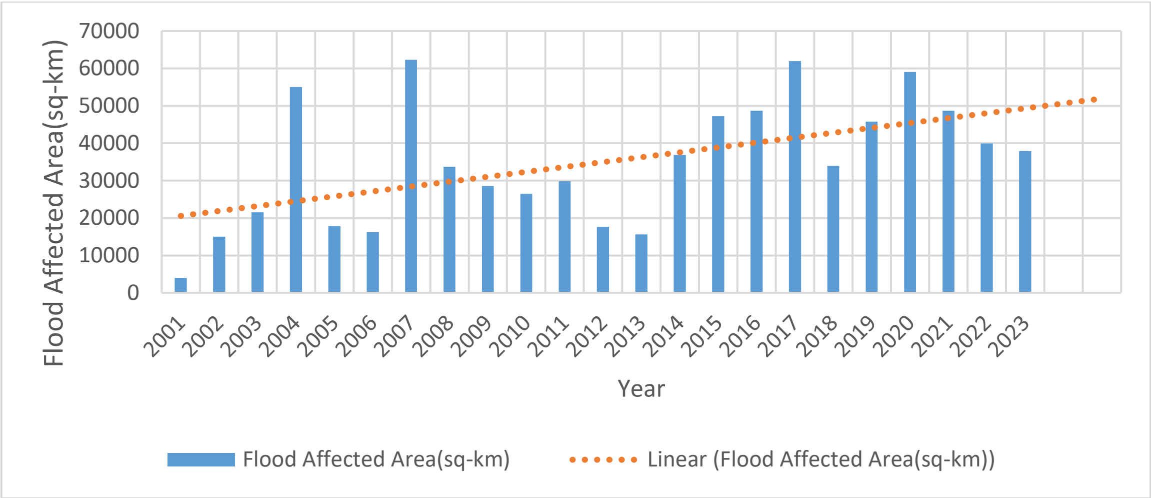

Figure 11: Linear regression analysis of flood affected area from year 2001-2023

- Description of key findings

Some key findings are identified and shared below from above Figure 10 analysis

a. Linear forecast of cyclone occurrence is upward for upcoming years which means no of cyclone occurrences will be increased in upcoming years.
b. During the last 23-year period from 2001-2023 in this twenty first century, the Bay of Bengal has generated about 17 cyclonic storms (average 0.73 storms per year).

Several key findings have been identified from above Figure 11 and Table 10 analysis of flood data from year 2001-2022.

a. Flood affected area will be increased in recent upcoming years in Bangladesh which is very much alarming.

b. From each year from 2001 to 2023, almost average 22.92% area of Bangladesh has been flooded according to Table 10. So, there is definite chance of flood occurrence in each upcoming year specially in the monsoon season July to September.

- Summary of findings.

From above key findings, below two major risks are identified due to climate change impacts in industrial marine fisheries sector in Bangladesh by analysis of historical data from different sources which is very much alarming in upcoming future based on linear regression analysis.

1) Flood
2) Cyclone

Finally, loss and damage caused by flood and cyclone in industrial marine fisheries sector is approximately 1568.82 million takas from the year 2015-2020 in Bangladesh.

4.3 Phase Four: Risk Evaluation Based on Case Study

- Introduction

In this fourth phase of risk evaluation, data has been collected from the case study which is a secondary source as per mentioned in research methodology section. In this phase, linear regression, correlational and financial analysis has been particularly applied to evaluate the identified risks which are flood and cyclone due to climate change in sea fish supply chain. From the case study industrial white sea fish supply chain data has been collected with proper justification of information sources.

- Presentation of Case Study Data

From the case study total it has been shared by related concerns that total monthly maximum fish production capacity per month is almost 1800 kg. Sea fish production data has been collected from year 2017 to 2023. Following data has been shared below in below Table 11. Since 2015, the government of Bangladesh imposes a 65-day annual ban from May 20th to July 23rd under the Marine Fisheries Ordinance of 1983 (Rule 19). Initially, this ban was imposed only on industrial trawling.

Month	2017	2018	2019	2020	2021	2022	2023
Jan	1559	1430	1497	1600	1530	1634	1512
Feb	1423	1390	1380	1402	1540	1415	1450
Mar	1666	1589	1650	1550	1640	1610	1580
Apr	1545	1520	1540	1653	1570	1520	1456
May	1421	1254	1510	1480	1400	1450	1108
Jun	680	510	550	408	650	600	550
Jul	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0
Sep	1389	1478	1430	1330	1052	1450	1278
Oct	1476	1558	1406	1430	1523	1256	1433
Nov	1559	1490	1256	1590	1560	1306	1609
Dec	1722	1733	1650	1680	1790	1743	1670
Total Production(kg)	14440	13952	13869	14123	14255	13984	13646
Average Monthly Production(kg)	1444	1395.2	1386.9	1412.3	1425.5	1398.4	1364.6

Table 11: Monthly Fish Production data from Year 2017 to 2023

From according to the sources during case study, no of days halted due to flood and cyclone in each year from 2017 to 2023 has been shared in below Table 12.

Month	2017	2018	2019	2020	2021	2022	2023	Total No of days halted
Jan								0
Feb								0
Mar								0
April								0
May		3		5			5	13

		(Cyclone)		(Cyclone)			(Cyclone)	
Jun								0
July								0
Aug				5 (Flood)	5 (Flood)		6(Flood)	16
Sep								0
Oct						5 (Cyclone)		5
Nov			3 (Cyclone)					3
Dec								0
Total Days of Fish Production Halted Due to Cyclone	0	3	3	5	0	5	5	21
Total Days of Fish Production Halted Due to Flood	0	0	0	5	5	0	6	16
Total Days of Fish Production Halted	0	3	3	10	5	5	11	37

Table 12: No Of Days Fish Production Halted due to Flood and Cyclone

- Detailed analysis

Form the case study data, correlational analysis has been conducted in below Table 13 considering two variables by following Equation 1 in literature review

a = Total Yearly Production in kg

b = Total No of Days of Fish Production Halted

Year	Total Yearly Production in kg(a)	Total No of Days of Fish Production Halted (b)	a= $(x_i-\bar{x})$	b= $(y_i-\bar{y})$	a×b= $(x_i-\bar{x})(y_i-\bar{y})$	a= $(x_i-\bar{x})^2$	b²= $(y_i-\bar{y})^2$
2017	14440	0	401.57	-5.29	-2122.59	161259.61	27.94
2018	13952	3	-86.43	-2.29	197.55	7469.90	5.22
2019	13869	3	-169.43	-2.29	387.27	28706.04	5.22
2020	14123	10	84.57	4.71	398.69	7152.33	22.22
2021	14255	5	216.57	-0.29	-61.88	46903.18	0.08
2022	13984	5	-54.43	-0.29	15.55	2962.47	0.08
2023	13646	11	-392.43	5.71	-2242.45	154000.18	32.65
Average	14038.43	5.29		Sum	-3427.86	408453.71	93.43

Table 13 Correlation analysis between Total Yearly Production and No of days Fish Production Halted

$$\bar{x} = 14038.43, \bar{y} = 5.29$$

$$\sum_{i=1}^{n}(xi - \bar{x})(yi - \bar{y}) = -3427.86$$

$$\sum_{i=1}^{n}(x_i - \bar{x})^2 = 408453.71$$

$$\sum_{i=1}^{n}(y_i - \bar{y})^2 = 93.43$$

$$Rxy = \frac{-3427.86}{\sqrt{408453.71 \times 93.43}} = \frac{-3427.86}{6177.52} = -0.55$$

The coefficient indicates that the total yearly production and no of days of fish production halted have a high negative correlation. This means no of days of fish production halted increases the risk level of reducing total yearly sea fish production.

Financial loss due to no of days halted of Sea fish production due to cyclone and flood has been calculated below by following the data mentioned in Table 11.

Monthly Average Fish Production considering data from 2017 to 2023 mentioned in Table 11= 1403.84 kg/month (approximately)

Daily Average Sea Fish Production=1403.84 ÷ 30=46.80 kg/day (approximately)

No of days Sea Fish Production Halted due to Cyclone and Flood in a year considering data from 2017 to 2023 mentioned in Table 12 = 5.28 days/year (approximately)

Average Production Loss per year due to cyclone and flood= 46.80 kg/day × 5.28 days/year= 247.08 kg/year (approximately)

Average Sea Fish Price confirmed by company concern = 700 taka/kg (approximately)

Average Sea Fish Production Loss due to Cyclone and Flood in a year

= 247.08 kg/year × 700 taka/kg = 172953.08 taka/year

=172953.08taka/year÷125takas

= $1383.62/year(approximately)

So, finally it can be evaluated from above case study that almost 247.08kg sea fish production has been lost per year by halting sea fish production due to flood and cyclone and almost 1383.62USD per year foreign earnings has been lost according to concern organization data.

- Statistical analysis

According to data of fish production in each year from 2017-2023 in Table 11, from which linear forecast trend of fish production in upcoming years has been depicted in Figure 12 and analyzed through excel linear regression.

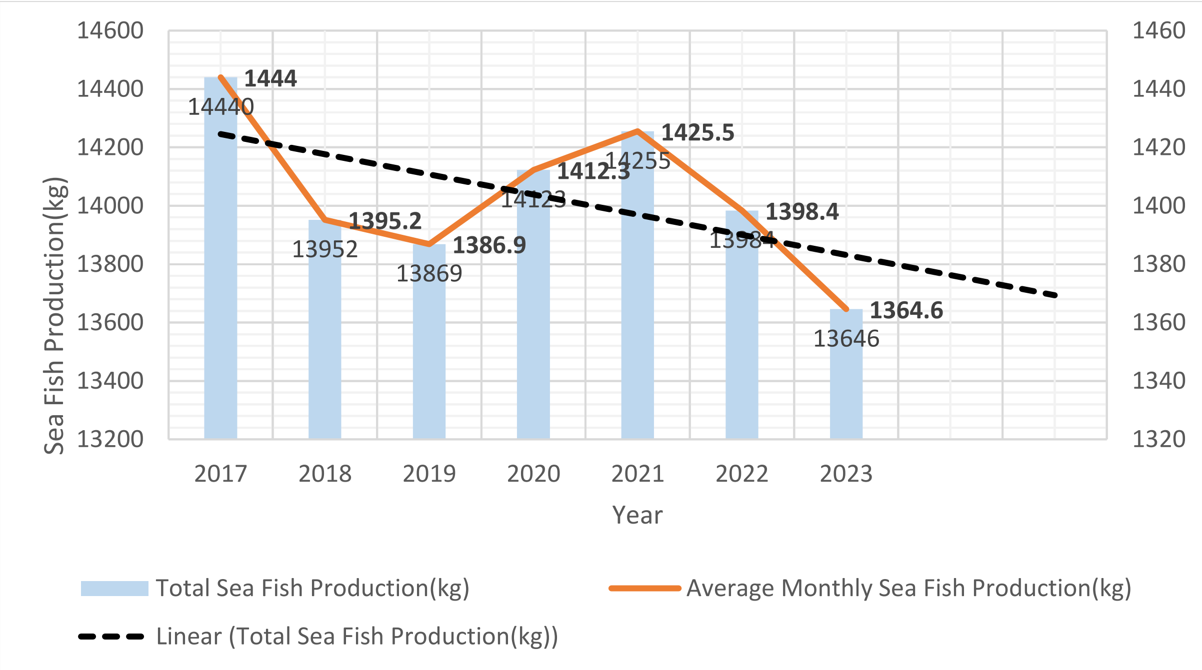

Figure 12: Linear regression of fish production from year 2017-2023

According to data of days halted of sea fish production from each year from 2017-2023 in Table 12, various linear forecast trends of sea fish production in upcoming years has been depicted in below Figure 13.

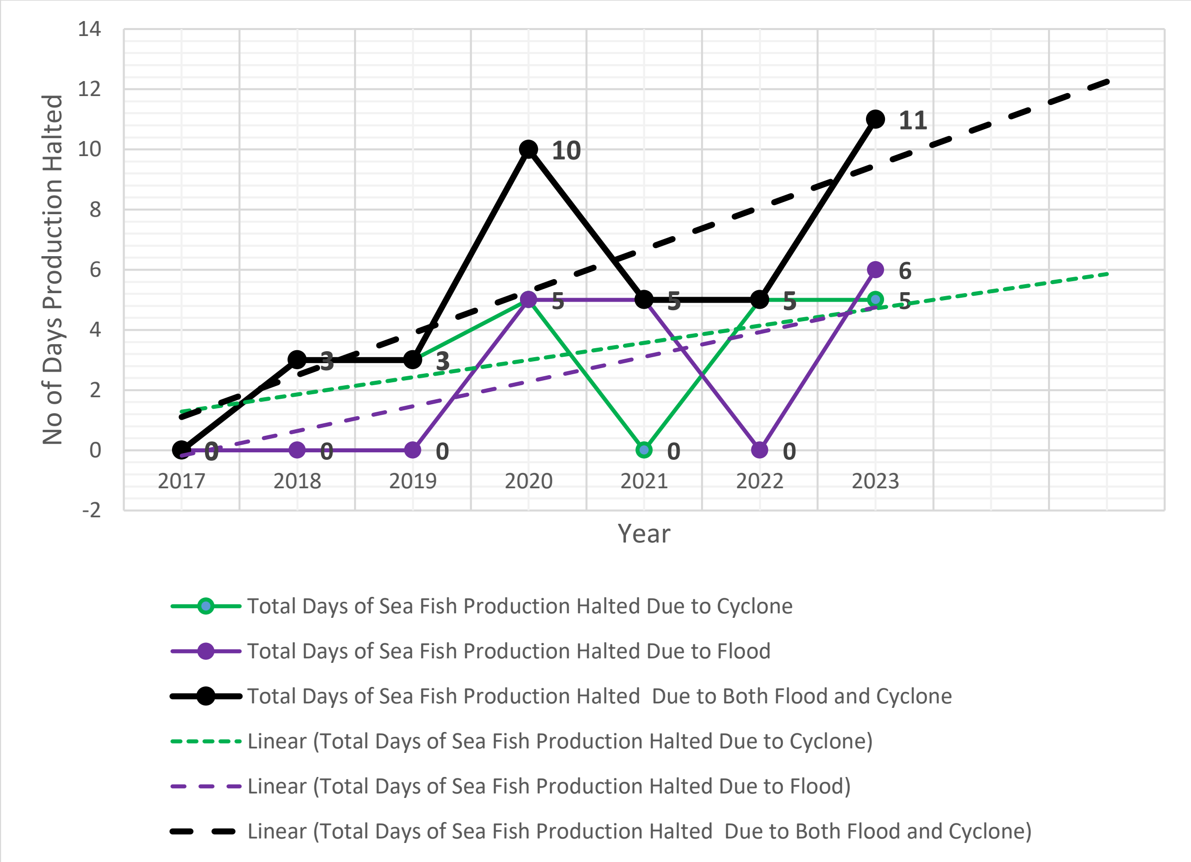

Figure 13: Linear regression of Sea fish production halted from year 2017-2023

According to data of sea fish production from Table 11 and no of days halted in each year from 2017-2023 by following Table 12, from which scatter diagram with linear correlation has been depicted in below Figure 14.

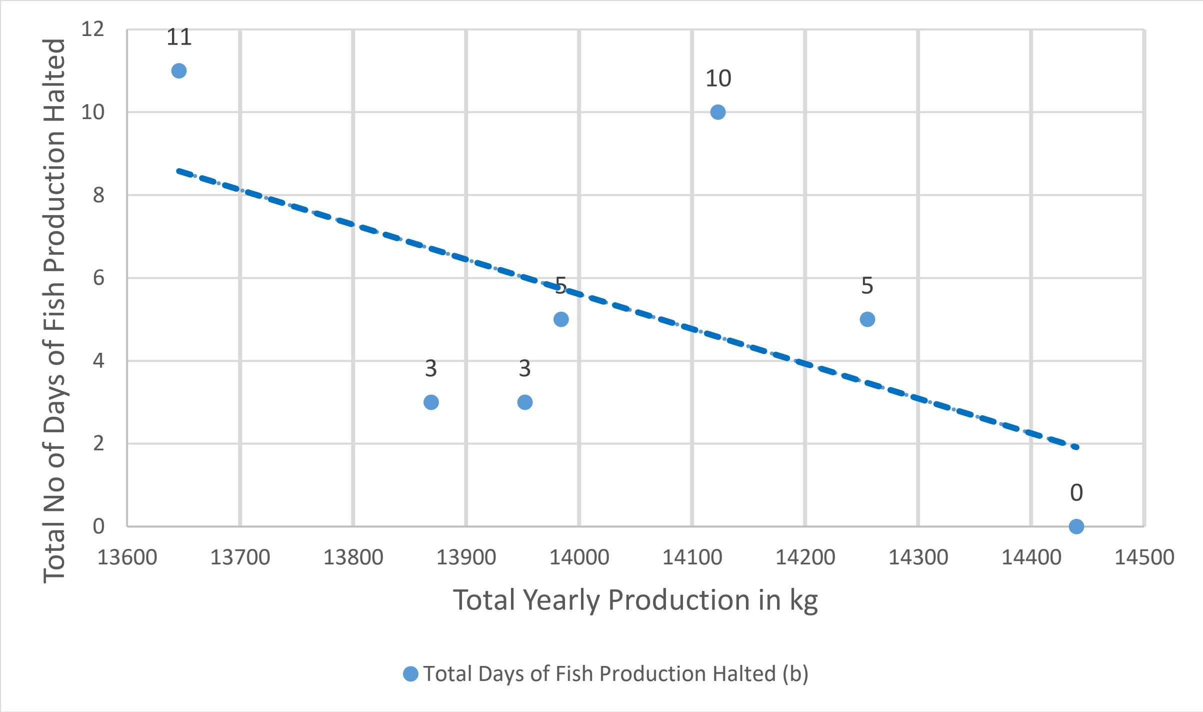

Figure 14: Scatter Diagram with Linear Correlation

- Description of key findings

Several significant facts have been evaluated from above Table 12 and Table 13.

a) From Table 12, total no of days sea fish production halted due to cyclone is 21 and flood is 16 from year 2017 to 2023 and probability of cyclone is in each year 71.42% and flood is in each year 42.85% especially coastal region of Bangladesh.

b) The negative correlation coefficient from Table 13, it has been proved that increasing no of days of fish production halted ultimately reduces total yearly sea fish production.

c) Now by combining the findings from Table 12 and Table 13, it can be said that greater probability of occurrences of cyclone than flood in coastal region of Bangladesh which ultimately affects sea fish production by halting sea fish production for several days.

Several key findings have been identified from above Figure 12 analysis of production data from year 2017-2023.

a. Total sea fish Production and Average fish Production gradually declined over the years from 2017 to 2023.
b. Future trend of sea fish production is going to be declined in upcoming years.

Several future predictions can be assumed from above Figure 13 and they are mentioned below.

a) Linear trend of no of days of fish production halted due to cyclone (green line) and flood (purple line) is upward which results more upward line of total no of days of fish production halted due to cyclone and flood (black line).
b) Linear trend is upward which means no of halted days due to cyclone and flood is going to be increased in recent upcoming years.

Several key findings have been identified from above Figure 14 analysis of scatter diagram with linear correlation data from year 2017-2023.

- There is a negative linear correlation when one variable which is No of days fish production halted increases as the other variable which is total yearly production decreases. This is shown by a downwards sloping straight regression line.
- Therefore, there is an inverse proportional relationship between total fish production and total no days of fish production halted in sea fish supply chain.

- Summary of findings.

From above key findings, below two major risks are identified due to climate change impacts in industrial marine fisheries sector in Bangladesh by analysis of historical data from case study which is very much alarming in upcoming future based on linear regression analysis.

1) Flood
2) Cyclone

So, finally it can be evaluated from above case study that almost 247.08 kg sea fish production has been lost per year by halting sea fish production due to flood and cyclone and almost 1383.62USD per year foreign earnings have been lost according to case study of concern organization.

Chapter 5

Discussion

In this chapter, future recommendations and guidelines are discussed which is followed by four phases according to risk management process in sea fish supply chain due to production fluctuations. Firstly, the strategy selection for risk treatment which is selected from few options. Secondly, implementation of strategies through different policies and procedures and thirdly, controlling risk according to risk management process. Finally, monitoring risks metrices of sea fish supply chain through continuous review. This chapter ultimately contains recommendations and guidelines from a risk management viewpoint which answers the ways to address productions fluctuations due to climate change in sea fish supply chain.

5.1 Phase Five: Strategy Selection for Risk Treatment

- Introduction

In this fifth phase of strategy selection for risk treatment, one or more risk treatment options have been selected based on based previous research publications to answer the most possible ways to address productions fluctuations due to climate change in sea fish supply chain. There are several risk treatments options which has been already discussed in details in literature review.

1. Risk Avoidance
2. Risk Prevention
3. Risk Acceptance
4. Risk Mitigation
5. Risk Sharing

- Discussion of important findings

In case of selecting the strategy for supply chain risk management, important findings must be considered based on risk analysis and evaluation in previous phases of risk management of sea fish supply chain. These major findings are mentioned below.

i. Flood and Cyclone are two main consequences due to climate change impact in sea fish supply chain for production fluctuations.
ii. Unknown Risks could be weather or acts of God such as floods, cyclone, tornados, hurricanes, fires etc. [17]. Therefore, both Flood and cyclone are unknown risks.
iii. Mitigation or risk responsiveness is essential when unknown risks are present. Not everything can be anticipated or prevented [23]. So, the best way to deal with unknown risks such as flood and cyclone is risk mitigation.
iv. Traditional remedy for such unknown risks is risk sharing through disaster insurance [17].

Finally, both risk mitigation and sharing strategies have been selected for to reduce the impact of production fluctuations in sea fish supply chain due to such unknown type of risks which are flood and cyclone.

- Future recommendations and guidelines

Risk mitigation strategies: The impact of such unknown risk events in sea fish production fluctuations such as flood and cyclone can be reduced by applying below mentioned risk mitigation strategies:

1) Establish the Risk Leadership Team

A continuous challenge facing organizations concerns how to develop a generation of leaders who understand how to make risk management a critical organizational competency. One way to link leadership and risk management is to make risk management responsibility an important part of executive leadership steering committees [45]. Therefore, a steering committee should be formed with assigning and delegating specific responsibilities to lead during any risk situations specially such type of unknown risk flood and cyclone.

2) Establish Risk Crisis Teams

These teams, staffed with the right professionals who have access to real-time data and information, are an indispensable part of the risk management process [45]. A risk crisis team should be formed to act immediately during any risk events which can affect sea fish production.

3) Create A Flexible Supply Chain

To be flexible means to be adaptable and responsive to change, including changes brought about by risk events. Flexibility provides choices, and choices directly support greater supply chain resiliency. Flexible supply chains are able to adapt quickly to changes or risk events, including disruptions to supply and changes in demand, while maintaining customer service levels [19]. To build a volume flexible sea fish supply chain, different supply chain tactics can be applied in different situations which is described below.

a) Follow Latest Weather forecast

Forecasting has always been a business challenge. However, it has become especially difficult over the past few years due to globalization, shortened product life cycles, and unforeseen disruptions [46] . Similar to other organizational and supply chain processes, forecasting needs to be flexible in order to be most effective in times of change [47]. Predict the demand efficiently and be able to plan the sea fish production is essential for entire both sea fish industry and supply chain. Forecasting the occurrence of unknown risks such as flood and cyclone which is very essential for sea fish supply chain perspective.

Flood forecasting and warning activities run from April to October every year in Bangladesh. In this period, the field-level hydrological measurements division works closely with the flood forecasting center to provide observed data. Flood Forecasting and Warning Centre (FFWC) in Bangladesh remains open 24 hours a day, 7 days a week during this period. Forecast indicators are mentioned below [48].

- Daily water level and rainfall situation reports
- Flood conditions summary (provided both in Bangla and English)
- Forecast bulletins for 24, 48, 72, 96 and 120 hours
- Rainfall surface map
- Flood inundation map
- Interactive voice response (mobile voice message)
- Special outlook
- Press briefing

Prediction of cyclonic storm in the Bay of Bengal and issuance of timely warning is the task of the Storm Warning Centre (National Weather Forecasting Centre) Dhaka. The cyclone information issued by the Storm Warning Centre (SWC) requires detection and monitoring of cyclones from formation until landfall and forecasting the cyclone's future track. Modern technology has provided the means for early detection and constant tracking. Warnings include the following below information [49].

- Position of storm center.
- Direction and rate of movement.
- Area likely to be affected specifying upazilas (administrative unit in Bangladesh) of the district if possible.
- Approximate time of commencement of gale winds (speed more than 32 km/h or 52 km/h).
- Maximum wind speed expected.
- Approximate height of storm surge/tide and areas likely to be affected.

According to Bangladesh Metrological department (BMD), maritime ports signals are mentioned in below Table 14 [50].

Signals	Meaning
Distant Cautionary Signal No. I	There is a region of squally weather (wind speed of 61 kms/hour) in the distant sea where a storm may form.
Distant Warning Signal No. II	A storm (wind speed of 62-88 kms/hour) has formed in the distant deep sea. Ships may fall into danger if they leave harbor.
Local Cautionary Signal No. III	The port is threatened by squally weather (wind speed of 40-50 kms/hour).
Local Warning Signal No. IV	The port is threatened by a storm (wind speed of 51-61 kms/hour) but it doesn't appear that the danger is as yet sufficiently great to justify extreme precautionary measures.
Danger Signal No. V	The port will experience severe weather from a storm of slight or moderate intensity (wind speed of 62-88 kms/hour) that is

	expected to cross the coast to the south of Chittagong port or Cox's Bazar port and to the east of Mongla port.
Danger Signal No. VI	The port will experience severe weather from a storm of slight or moderate intensity (wind speed of 62-88 kms/hour) that is expected to cross the coast to the north of the port of Chittagong or Cox's Bazar and to the west of the port of Mongla.
Danger Signal No. VII	The port will experience severe weather from a storm of light or moderate intensity (wind speed of 62-88 kms/hour) that is expected to cross over or near the port.
Great Danger Signal No. VIII	The port will experience severe weather from a storm of great intensity (wind speed of 89 kms/hour or more) that is expected to cross the coast to the south of the port of Chittagong or Cox's Bazar and to the east of the port of Mongla.
Great Danger Signal No. IX	The port will experience severe weather from a storm of great intensity (wind speed of 89 kms/hour or more) that is expected to cross the coast to the north or the port of Chittagong or Cox's Bazar and to the west of the port of Mongla.
Great Danger Signal No. X	The port will experience severe weather from a storm of great intensity (wind speed of 89 kms/hour or more) that is expected to cross over or near the port.
Failure of Communication No. XI	Communications with the Storm Warning Centre have broken down and local officers consider that a devastating cyclone is following.

Table 14: Maritime Port Signals [50]

According to Bangladesh Metrological department (BMD), river ports signals are mentioned in below Table 15 [50].

Signals	Meaning
Cautionary Signal No. I	The Area is threatened by squally winds of transient nature.
Warning Signal No. II	A storm is likely to strike the area (Vessels of 65 feet and under in length are to seek shelter immediately)
Danger Signal No. III	A storm will strike the area (all vessel will seek shelter immediately)
Great Danger Signal No. IV	A violent storm will soon strike the area (all vessels will take shelter immediately)

Table 15: River Port Signals [50]

b) Collaborative Planning, Forecasting and Replenishment (CPFR)

A successful forecasting option is to rely on collaborative forecasting efforts with supply chain members rather than developing the forecast alone. One such effort is Collaborative Planning Forecasting and Replenishment (CPFR), which is a joint process between two trading partners that establishes formal guidelines for joint forecasting and planning [47]. It is an approach to the supply chain process which focuses on joint practices. This is done through cooperative management of inventory through joint visibility and replenishment of products throughout the supply chain. Information shared between suppliers and retailer aids in satisfying customer demands through a system of shared information. Collaborative Planning, Forecasting, and Replenishment is a nine-step approach to improving supply chain management, and ties demand planning and supply planning into one process [51]. The model as shown in Figure 15 is a simplified version of the 9-step model. The model comprises of nine steps into three different phases and it has been described based on sea fish supply chain.

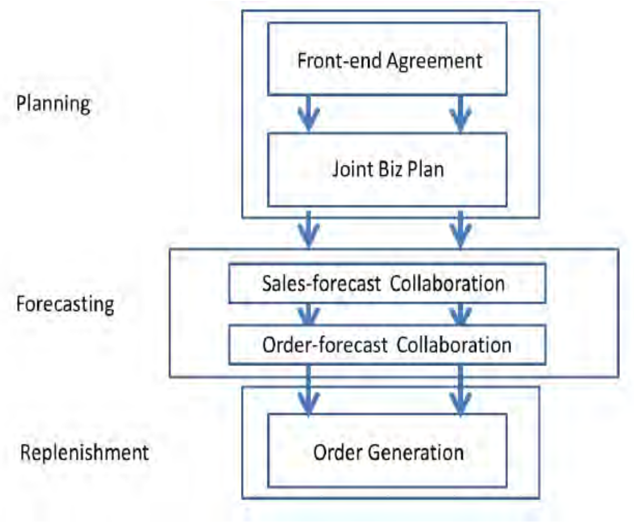

Figure 15: CPFR Model [51]

In the planning phase, there are 2 stages [51]:

i. Develop Front End Agreement: The agreement should include the guidelines and rules for collaborative relationship, a common basis for co-operation, trust and availability of competency resources, mechanism to handle disagreements and differences and measure specific KPIs for all parties such as retailer and intermediaries, owners of trawlers.

ii. Create the Joint Business Plan: The parties involved in sea fish supply chain create a business plan that should take into account their individual business strategies and defined category roles, objectives and tactics. This includes fish types, minimum order quantities, lead time and order frequency.

In the forecasting phase, there are 6 stages [51]:

iii. Create the Sales Forecast: Retailer point-of-sales data, causal information is used by retailer to create an initial sales forecast. This forecast should be then communicated to the other parties of sea fish supply chain such as agents and wholesalers used as a baseline for the creation of an order forecast.

iv. Identify Exceptions for Sales Forecast: The identified criteria for exceptions such as special fish items which are seasonal and rare, sudden demand fluctuations of regular items should be stated in the Front-end Agreement. Moreover, any kind of production disruption due to any artificial or natural reasons such as flood and cyclone must be considered.

v. Resolve/Collaborate on Exceptions: Exceptional or special items should be easily identified and information are sent to reconcile special and seasonal fish items. Any exceptions in supply chain such as forecasting the occurrence of unknown risks such as flood and cyclone must be informed in advance. Any fluctuations in production and demand of regular items must be informed to concern stakeholders.

vi. Create Order Forecast: The order forecast relies on point-of-sale (POS) data, causal information, weather forecast and current inventory status to generate a specific forecast that supports the shared sales forecast.

vii. Identify Exceptions for Order Forecast: Two types Exceptions are identified and should be considered. Firstly, any type of production disruption caused by either artificial or natural disasters such as flood and cyclone. Secondly, demand of seasonal and special rare fish items.

viii. Resolve/Collaborate on Exceptions: The parties may negotiate (if necessary) to produce an adjusted order forecast considering exceptions.

In the replenishment phase, the single stage is [51]:

ix. Order Generation: The final step in the CPFR process is generating the order and promising the delivery. The order forecast should be translated into a firm order by one of the parties involved in sea fish supply chain.

c) Add temporary workforce as spare capacity

Companies sometimes refer to base capacity as their normal needs, and reactive capacity is needed for unexpected events. Then spare capacity is more flexible than stock. The alternative is to build spare capacity into a process, typically in its facilities, operations, transport, staffing levels, etc. There are many ways of providing extra capacity, such as building bigger facilities, renting or leasing facilities at short notice, subcontracting operations, moving to build-to-order operations or adjusting work patterns (perhaps by changing shifts or product mixes). All of these can increase operating costs and reduce efficiency, but they may be the best way of avoiding disruptions [52]. In case of sea fish supply chain additional industrial trawler and manpower like fishermen can be added to reduce the production loss during flood and cyclone during non-breeding season of fish. In other way, subcontracting to a third party can be a good option for sea fish production to meet customer demand during non-breeding season.

d) Maintain the safety stock level

A firm always needs some basic working stocks for its normal operations and to allow for risks it needs additional safety stock. This safety stock is above the company's perceived needs, but it holds it to allow for any unforeseen events. Such stocks do not give a long-term solution, but they overcome immediate problems and allow a firm to plan its recovery after any disruption. Unfortunately, they also bring their own risks of tied-up investment, damage, obsolescence and so on and they have the major disadvantage of hiding underlying problems in operations [52]. The amount varies in different fields and depends on how variable is the supply and how uncertainty is the demand. As sea fish is perishable item, therefore the stock amount and time duration with proper temperature must be maintained.

4) Establish Supply chain Visibility through RFID

Visibility of the supply network can help a company anticipate a disruption and mitigate their effects when they do occur. Part of the visibility is having a clear picture of the location and form of inventories in the supply network, whether they are in raw material form, work in process, stored at a warehouse location, or are in transit. Then when a disruption does occur, a company can respond more effectively as it knows which resources to marshal and how to manage them. Also, having a process in place that provides clear visibility gives reassurance to customers that the company has the foresight to devise an appropriate response to a disruption [47].

Radio Frequency Identification (RFID) uses memory chips equipped with tiny radio antennas that can be attached to objects that transmit streams of data about the object. For example, RFID can be used to identify any product movement. RFID has had tremendous use in monitoring inventory control. The visibility provided by RFID gives accurate knowledge of inventory levels and can eliminate any discrepancy between a physical count and inventory records, also reducing labor costs since a physical count isn't needed [47]. So, RFID tags can be introduced in sea fish supply chain by sorting different fish types and allocating unique RFID tags for each type of fish. In case of sea fish production fluctuations, different types of sea fishes can be easily identified through RFID technology which shares accurate knowledge of inventory levels. Such accurate inventory levels help to take urgent decision for future directions to fulfill customer demand.

5) Make Contingency Plans

Contingency plans come into effect after a risky event actually occurs. A contingency plan is often referred to as 'plan B', which is only activated when an event occurs and changes are needed to the usual ‘plan A’ operations [53]. For example, a company’s normal plans might include moving goods like sea fish by low-cost road transport, but if there is a sudden emergency order it has a contingency plan of using higher-cost air freight due to such production fluctuations in sea fish supply chain to meet customer demand.

6) Business Continuity/Disaster Recovery Plans

An effective way to respond to unknown risks is to develop and practice response scenarios, what we call business continuity planning. Business continuity is the process of planning for and implementing procedures that are designed to enable continuous operations of critical business processes and functions. The goal of the creation and implementation of business continuity and disaster recovery plans is to minimize economic losses resulting from disruptions to business functions [17]. In case production fluctuations in sea fish supply chain due to such natural disasters like flood and cyclone, the business continuity/disaster recovery plans address how to do the following:

i. Provide a plan of action to facilitate an orderly recovery of technical infrastructure and critical business processes of sea fish.
ii. Identify key individuals or teams who will manage the process of recovering and restoring the sea fish business and/or technology after a natural disaster
iii. Specify the critical and technical activities of sea fish business that need to continue after a natural disaster
iv. Outline the logistics of recovering critical sea fish business processes and technical infrastructure.

Risk sharing strategy: Insurance is the most common way of risk sharing strategy that formally transferring risk from one organization to another. This has an insurance company accepting the risk of, say, a fire in return for an agreed premium. The essence of insurance is that the potential loss from a risk is too high for one organization to accept, but an insurance company can pool the risks from a large number of organizations and share the costs [53].

In case of sea fish supply chain, a risk pool can be formed by accumulating all industrial trawler owners or a separate association of industrial trawler owners can be formed which will be performed as a risk pool through involving insurance companies. A risk pool involves insurance companies controlling the risk of insuring against catastrophic events such as flood and cyclone. If a claim arises from a natural disaster or catastrophic weather event, the insurance companies spread losses among all members of the risk pool.

5.2 Phase Six: Selected Strategy Implementation

- Introduction

In this sixth phase of risk treatment strategy implementation, several ways to implement the risk treatment options have been discussed which fulfills the answer of the most possible ways to address productions fluctuations due to climate change in sea fish supply chain. Strategy implementation is an iterative process of implementing strategies, policies, programs and action plans that allows a firm to utilize its resources to take advantage of opportunities in the competitive environment.

- Discussion of important findings

Since already risk treatment strategies have been selected in above phase five. Two major risk treatment findings are mentioned below.

1) Risk mitigation strategies: Different risk mitigation strategies are summarized as below.

    - Establish the Risk Leadership Team

- ➢ Establish Risk Crisis Teams
- ➢ Create A Flexible Supply Chain through latest weather forecasting with CPFR, adding spare capacity and safety stock level
- ➢ Establish Supply chain Visibility through RFID
- ➢ Make Contingency Plans
- ➢ Business Continuity/Disaster Recovery Plans

2) Risk sharing strategy: Only risk sharing strategy is insurance.

- Future recommendations and guidelines

Now below guidelines can be followed as implementation process to reduce production fluctuations in sea fish supply chain due to the impacts of climate change.

1) Establish risk leadership team to implement risk strategies.
2) Establish risk crisis teams to act promptly in any emergency during risk events.
3) Both flood and cyclone forecasting activities must be followed as per government instructions.
4) Follow the maritime port signals during cyclone formation.
5) Digitalization of sea fish supply chain data to implement CPFR model and to ensure supply chain visibility.
6) Synchronized forecasting of sales and weather should be maintained to implement CPFR model and avoid any kind of supply chain disruption.
7) Additional workforce allocation for fishing to meet customer demand during non-breeding season of fishes.
8) Regular updating of data and monitoring of sea fish stock level at cold storage.
9) Maintain safety stock level at cold storage according to customer demand.

10) Proper temperature should be maintained during inventory management of sea fish at cold storage.
11) Implementation of RFID technology throughout the supply chain to ensure visibility with better inventory control and security.
12) Both central and local government should continuously monitor and inform to coastal people and fishermen regarding contingency plans in case of any emergency situation arise.
13) Prepare a business continuity/disaster recovery plan immediately after a natural disaster.
14) Implement a business continuity/disaster recovery plan by involving key individuals and teams like risk leadership team, risk crisis teams.
15) Reestablish key technical infrastructure and continue critical business processes of sea fish after a natural disaster within the shortest possible time.
16) Risk pool should be formed to mitigate the loss due to natural disasters.
17) Private fishing firms, owners of trawlers and other intermediaries should take initiative to implement above strategies.
18) Government bodies should help to implement above strategies.

5.3 Phase Saven: Risk Control

- Introduction

In this seventh phase of risk control, one or more risk treatment options have been evaluated after implementation of strategies that justifies the most possible ways to address productions fluctuations due to climate change in sea fish supply chain. The purpose of the control phase's is to evaluate the progress obtained through the implemented strategies which has been mentioned in above sixth phase.

- Discussion of important findings

Since already risk treatment strategies have been implemented by following guidelines mentioned in above phase six. Two major findings are mentioned below.

1) Any deviations in information.
2) The strategy does not fulfill the expected goal.

- Future recommendations and guidelines

Now below risk control guidelines can be followed as to reduce production fluctuations in sea fish supply chain due to the impacts of climate change. In this phase basically the strategies that have been already implemented is to be evaluated through

1) Continuous review.
2) Regular updates of information.
3) Continuous reporting
4) Establish possible corrective actions in case there are any deviations and/or the strategy does not fulfill the expected goal.

5.4 Phase Eight: Risk Monitoring

- Introduction

In this final and eighth phase of risk monitoring, which consists of supervising the sea fish chain in order to detect new risks, identify tendencies, probabilities and impacts due to climate change. The purpose of the risk monitoring phase's is to observe the progress obtained through the implemented strategies which has been mentioned in above phases.

- Discussion of important findings

In case of production fluctuations in sea fish supply chain below indicators or metrices can be followed for risk monitoring.

a) Likelihood of Occurrences of risk events such as flood and cyclone
b) Forecasting accuracy
c) The extent of impact of such risk events
d) Damage and loss due to risk events
e) Sea fish production measurements
f) Inventory accuracy
g) Order fulfilment rate

- Future recommendations and guidelines

Reports on risk monitoring can be combined with existing experts' reviews and meetings. Monitoring can also include monitoring qualitative sources of information such as news or weather reports to identify events that are precursors to risks.

Chapter 6

Summary, Limitations and Conclusion

6.1 Summary

As already mentioned in context phase of above chapter 3, that white sea fish supply chain network in domestic market is the most complex type which has been depicted in figure 8 due to having presence of the greatest number of intermediaries. In chapter four by following phase two and three, unknown risk events such as flood and cyclone have been identified and analyzed. In this chapter four, risks are evaluated based on case study data. Afterwards, then risks mitigation strategies has been selected and discussed in details in following phase five in the chapter five. By following the implementing recommendations in phase six, a proactive sea fish supply chain has been designed as below in Figure 16.

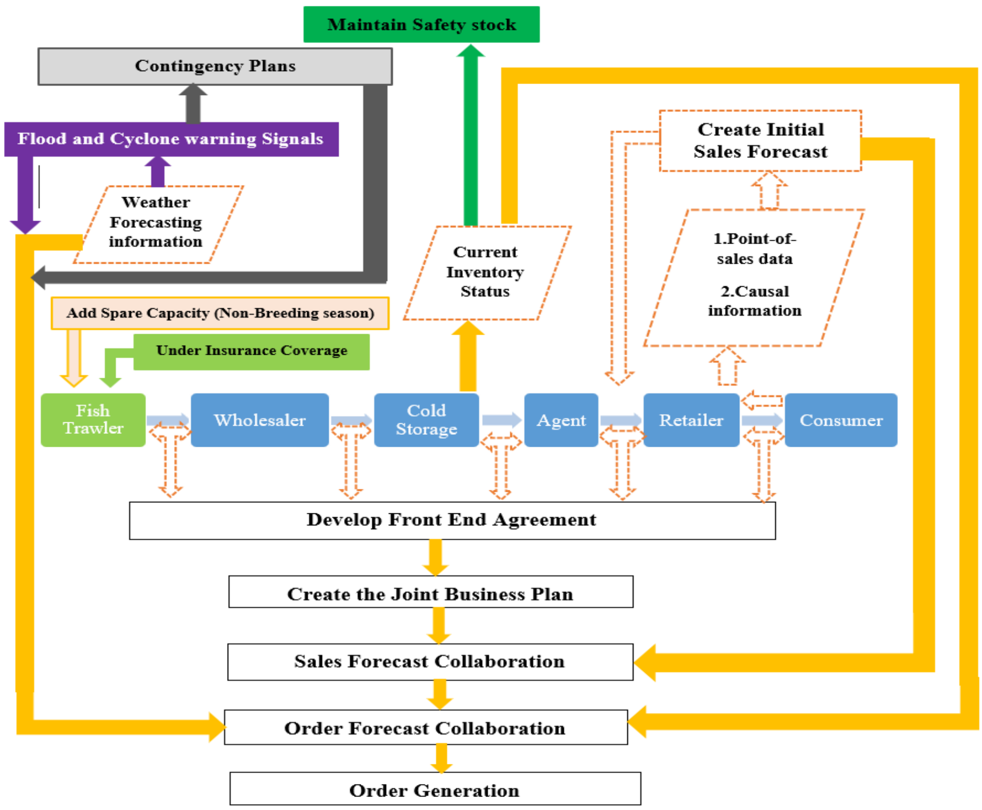

Figure 16: Proactive Sea Fish Supply Chain Mapping

6.2 Limitations

There are several limitations of following research. Firstly, many current data and documents are not available, which would have made the research more informative. Some desired information could not be collected due to the confidentiality of the sources. Secondly, Cost benefit analysis regarding risk mitigation and implementation is not included in this research due to its complexity additionally more detailed research is required for proper analysis and justification of cost benefit analysis.

6.3 Conclusion

In many regions of the world, natural hazards such as tsunamis, droughts, earthquakes, hurricanes, and floods are a constant threat to societies in general and to firms in particular. The negative consequences on supply chains are obvious since production facilities and transportation are highly vulnerable to natural disasters.

Sea fish supply chain in Bangladesh is overwhelmed with a number of unresolved issues. Due to the geographical position, weather condition and long sea area of Bangladesh has great opportunity to become one of the big producers of marine fish all over the world. However, climate change scenarios threat the opportunity to become one the of the largest sea fish producers in the world. To improve fish supply chain by enduring production fluctuations, a new supply chain is required with adequate modification. By the proper application and digitalization of information system, it is possible to make the supply faster and efficient. The proposed CPFR model with proper forecasting according to necessary recommendations can certainly minimize the impact of production fluctuations of the sea fish supply chain in Bangladesh.

References

[1] Leadley, P., Pereira, H. M., Alkemade, R., Fernandez-Manjarrés,J. F., Proença, V., Scharlemann, J. P. W., "Biodiversity Scenarios: Projections of 21st century change in biodiversity and associated ecosystem services," Secretariat of the Convention on Biological Diversity, Montreal, 2010.

[2] Core Writing Team, H. Lee and J. Romero (eds.), "Climate Change 2023: Synthesis Report," Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland, 2023.

[3] Blasiak, R., Spijkers, J., Tokunaga, K., Pittman, J., Yagi, N., Österblom, H., "Climate change and marine fisheries: Least developed countries top global index of vulnerability," *PLoS One,* vol. 12, no. 6, pp. 1-15, 2017.

[4] DoF (2023), "Yearbook of Fisheries Statistics of Bangladesh 2021-22," Fisheries Resources Survey System (FRSS), Department of Fisheries (DoF); Ministry of Fisheries and Livestock, Government of People's republic of Bangladesh, 2023.

[5] *The Bay of Bengal Maritime Boundary Arbitration between the People's Republic of Bangladesh and India,* 2014.

[6] *Delimitation of the maritime boundary in the Bay of Bengal (Bangladesh/Myanmar),* 2012.

[7] Fernandes, J. A., Kay, K., Hossain, M., Ahmed, M., Cheung, W., Lazar, A. N., & Barange, M., "Projecting marine fish production and catch potential in Bangladesh in the

21st century under long-term environmental change and management scenarios," *ICES Journal of Marine Science*, vol. 73, no. 5, pp. 1357-1369, 2016.

[8] Becker, M., Papa, F., Karpytchev, M., Delebecque, C., Krien, Y., Khan, J. U., Ballu, V., Durand, F., Le Cozannet, G., Islam, A. K. M. S, Calmant, S. & Shum, C. K., "Water level changes, subsidence, and sea level rise in the Ganges–Brahmaputra–Meghna delta," *Proceedings of the National Academy of Sciences,* vol. 117, no. 4, pp. 1867-1876, 2020.

[9] World Meteorological Organization (WMO), "Climate," [Online]. Available: https://wmo.int/topics/climate.

[10] United Nations, "What Is Climate Change," [Online]. Available: https://www.un.org/en/climatechange/what-is-climate-change.

[11] Kamaluddin, A. M. and Kaudstaal, R., "Delineation of the Coastal Zone," Program Development Office for Integrated Coastal Zone Management Plan(PDO-ICZMP), Dhaka, 2003.

[12] Hossen, M. F. & Sultana, N., "Shoreline change detection using DSAS technique: Case of Saint Martin Island, Bangladesh," *Remote Sensing Applications: Society and Environment,* vol. 30, p. 100943, 2023.

[13] Sarker, S., Hussain, F. A., Assaduzzaman, M. and Failler, P. , "Blue Economy and Climate Change: Bangladesh Perspective," *Journal of Ocean and Coastal Economics,* vol. 6, no. 2, 2019.

[14] Sarwar, M. G. M., "Impacts of Sea Level Rise on the Coastal Zone of Bangladesh," Lund University, Lund, 2005.

[15] Azad, A., "Supply Chain Management of Marine Fish- A Case Study on Bangladeshi Fishing Trawler Company," *IOSR Journal of Business and Management (IOSR-JBM)*, vol. 20, no. 10, pp. 24-29, 2018.

[16] ISO 31000:2018, "Risk management — Guidelines," 2018. [Online]. Available: https://www.iso.org/standard/65694.html.

[17] Schlegel, G. L. and Trent, R. J., "Operational Risk," in *Supply Chain Risk Management: An Emerging Discipline*, New York, CRC Press, 2014, pp. 134-143.

[18] Chopra, S. and Meindl, P., "Understanding The Supply Chain," in *Supply chain management: Strategy, planning and operation*, New Jersey, Pearson Education, 2013, p. 1.

[19] Stevenson, M. and Spring, M. , "Flexibility from a Supply Chain Perspective: Definition and Review," *International Journal of Operations Management*, vol. 27, no. 2, pp. 685-713, 2007.

[20] Christopher, M., "Logistics, the supply chain and competitive strategy," in *Logistics & Supply chain Management*, Dorset, Pearson Education Limited, 2011, p. 3.

[21] Waters, D., "Working with risk," in *Supply chain risk management : vulnerability and resilience in logistics*, London and Philadelphia, Kogan Page Limited, 2007, p. 7.

[22] Zsidisin, G. A. and Ritchie, B., "Supply Chain Risk Management – Developments, Issues and Challenges," in *Supply Chain Risk*, New York, Springer, 2009, p. 3.

[23] Schlegel, G. L. and Trent, R. J., "Supply Chain Risk Management: Setting the Stage," in *Supply Chain Risk Management: An Emerging Discipline*, New York, CRC Press, 2014, pp. 18-22.

[24] Jüttner, U., Peck, H. and Christopher, M., "Supply chain risk management: outlining an agenda for future research," *International Journal of Logistics Research and Applications*, vol. 6, no. 4, p. 197–210, 2003.

[25] Dani, S., "Predicting and Managing Supply Chain Risks," in *Supply Chain Risk*, New York, Springer, 2009, p. 58.

[26] Norrman, A. and Jansson, U., "Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident," *International Journal of Physical Distribution & Logistics Management*, vol. 34, no. 5, pp. 434-456, 2004.

[27] Hallikas, J., Karvonen, I., Pulkkinen, U., Virolainen, V. M., Tuominen, M., "Risk management processes in supplier networks," *International Journal of Production Economics*, vol. 90, no. 1, pp. 47-58, 2004.

[28] Oehmen, J., Ziegenbein, A., Alard, R., & Schönsleben, P., "System-oriented supply chain risk management," *Production Planning & Control*, vol. 20, no. 4, p. 343–361, 2009.

[29] Bradley, J. R., "An improved method for managing catastrophic supply chain disruptions," *Business Horizons*, vol. 57, no. 4, pp. 483-495, 2014.

[30] Berle, Ø., Asbjørnslett, B. E., Rice, J. B., "Formal Vulnerability Assessment of a maritime transportation system," *Reliability Engineering & System Safety*, vol. 96, no. 6, pp. 696-705, 2011.

[31] Lavastre, O., Gunasekaran, A. and Spalanzani, A., "Effect of Firm Characteristics, Supplier Relationships and Techniques Used on Supply Chain Risk Management (SCRM): An Empirical Investigation on French Industrial Firms," *International Journal of Production Research*, vol. 52, no. 11, pp. 3381-3403, 2014.

[32] Schlegel, G. L. and Trent, R. J., "Emerging Risk Management Tools, Techniques, and Approaches," in *Supply Chain Risk Management: An Emerging Discipline*, New York, CRC Press, 2014, p. 226.

[33] Elleuch, H., Hachicha, W. and Chabchoub, H., "A combined approach for supply chain risk management: description and application to a real hospital pharmaceutical case study," *Journal of Risk Research*, vol. 17, no. 5, pp. 641-663, 2013.

[34] Kern, D., Moser, R., Hartmann, E. and Moder, M. , "Supply risk management: model development and empirical analysis," *International Journal of Physical Distribution & Logistics Management*, vol. 42, no. 1, pp. 60-82, 2012.

[35] Diabat, A., Govindan, K. and Panicker, V. V., "Supply chain risk management and its mitigation in a food industry," *International Journal of Production Research*, vol. 50, no. 11, pp. 3039-3050, 2011.

[36] Fazli, S., Kiani, R. M. & Vosooghidizaji, M., "Crude oil supply chain risk management with DEMATEL–ANP," *Operations Research*, vol. 15, pp. 453-480, 2015.

[37] Waters, D., "Analysing risks," in *Supply chain risk management : vulnerability and resilience in logistics*, London and Philadelphia, Kogan Page Limited, 2007, p. 130.

[38] Faizal, K. and Dr. PL. K. Palaniappan, "Risk Assessment and Management in Supply Chain," *Global Journals of Research in Engineering*, vol. 14, no. G2, pp. 19-30, 2014.

[39] Mullai, A., "Risk Management System – A Conceptual Model," in *Supply Chain Risk*, New York, Springer, 2009, p. 88.

[40] Waters, D., "Identifying risks," in *Supply chain risk management : vulnerability and resilience in logistics*, London and Philadelphia, Kogan Page Limited, 2007, p. 110.

[41] wikipedia, "Pareto principle," [Online]. Available: https://en.wikipedia.org/wiki/Pareto_principle.

[42] Rosenthal, S., "Regression Analysis, Linear," 2017. [Online]. Available: https://onlinelibrary.wiley.com/doi/10.1002/9781118901731.iecrm0208.

[43] Prematunga, R. K., "Correlational analysis," *Australian Critical Care,* vol. 25, no. 3, pp. 195-199, 2012.

[44] BBS (2023), "Yearbook of Bangladesh 2023," Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division (SID), Ministry of Planning, Government of People's republic of Bangladesh, 2024.

[45] Schlegel, G. L. and Trent, R. J., "Future Directions in Supply Chain Risk Management," in *Supply Chain Risk Management: An Emerging Discipline,* New York, CRC Press, 2014, pp. 294-296.

[46] Sanders, N. R., "APICS Magazine," *Getting the Best Forecast by Combining Judgmental and Statistical Methods,* p. 29–32, 2006.

[47] Chad, A. and Sanders, N., "Supply Chain Security: A Dynamic Capabilities Approach," in *Supply Chain Risk*, New York, Springer, 2009, pp. 315-322.

[48] FFWC, "Flood Forecasting and Warning Centre," Bangladesh Water Development Board, Government of People's republic of Bangladesh, [Online]. Available: https://ffwc.gov.bd/app/home.

[49] BMD, "Bangladesh Metrological department," Ministry of Defense, Government of People's republic of Bangladesh, [Online]. Available: https://live8.bmd.gov.bd//.

[50] Bangladesh Metrological department, "Signals," [Online]. Available: https://live8.bmd.gov.bd/p/Signals.

[51] Edwards, J. D., "CPFR — COLLABORATIVE PLANNING, FORECASTING, AND REPLENISHMENT: Delivering Results for Manufacturers Serving the Retail Sector," A White Paper, 2003.

[52] Waters, D., "Creating resilient supply chains," in *Supply chain risk management : vulnerability and resilience in logistics*, London and Philadelphia, Kogan Page Limited, 2007, pp. 204-205.

[53] Waters, D., "Responding to risks," in *Supply chain risk management : vulnerability and resilience in logistics*, London and Philadelphia, Kogan Page Limited, 2007, pp. 154-156.

Appendix

This questionnaire has been designed for academic use only. It aims to demonstrate the sea fish supply chain details in Bangladesh.

Section A: General Information

Answer the following questions by ticking alongside your choice.

1. What is your name?

2. What is your current job associated with sea fish? / What's your role in sea fish supply chain?

a) Government/Company Officials

b) Fisherman/Trawler Owner

c) Agents/Cold Store Concerns

d) Others (please specify)

2. How long have you been in this job?

I) Below 5 years

II) 5 – 10 years

III) 11 - 20 years

IV) Over 20 years

Section B: Detailed questionaries for participants (interviewee)

Interview Questions	Interviewee						
	Government Officials	Company Officials	Fishermen	Trawler Owner	Agents/ Brokers	Cold Store Concerns	Others
How does sea fish supply chain operate in Bangladesh?	Asked	Asked	N/A	N/A	N/A	N/A	N/A
Who are the intermediaries of sea fish supply chain?	Asked	Asked	Asked	Asked	N/A	N/A	N/A
What are the functions of various intermediaries?	Asked	Asked	N/A	N/A	N/A	N/A	N/A
What is the bidding/tendering process?	Asked	Asked	Asked	Asked	N/A	N/A	N/A
Explain details about bidding/tendering process	Asked	Asked	Asked	Asked	Asked	N/A	N/A
Explain details about your regular job responsibilities	Asked	Asked	Asked	Asked	Asked	Asked	Asked