Climate risk assessment for fisheries and aquaculture based adaptation in Myanmar

Prepared By:

Mark Dubois, Kimio Leemans, Michael Akester, Shwu Jiau Teoh, Bethany Smith, Hsu Mon Aung, Tinzar Win Pyae Kyaw, May Hsu Mon Soe & KuMuDara Win Maung

WorldFish

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Photos on front cover (Akester, M):

1. Daw Ma Cho, fish collector and fish value addition entrepreneur from Papin Village, Maubin, Ayeyarwady Region with daughter and husband.
2. The Maubin floodplain fishery in the monsoon season.

Table of Acronyms

ADS – Agricultural Development Strategy

AHP – Analytic Hierarchy Process

DALMS – Department of Agricultural Land Management and Statistics

DDRR – Department of Disaster Risk Reduction

DoA – Department of Agriculture

DoF – Department of Fisheries

DRD – Department of Rural Affairs

EWS – Early Warning System

GAD – General Administrative Department

GFF – Global Environment Facility

FAO – Food and Agriculture Organisation of the United Nations

FD – Forestry Department

GEF – Global Environment Facility

GoM – Government of Myanmar

IPCC – International Panel on Climate Change

IWUMD – Irrigation and Water Utilisation Management Department

LDCF – Least Developed Countries Fund

LOA – Letter of Agreement

NAPA – National Adaptation Plan of Action

NPOA – National Plan of Action

Executive Summary

Myanmar is the second largest country in the Southeast Asia region with an estimated population of 54 million. Rice and fish dominate diets with per capita fish consumption at around 25kg/person/annum. Fisheries and aquaculture are important sub-sectors in Myanmar. According to the Department of Fisheries (DoF) statistics, the total production of fish in 2018 was 5,877,000 MT, of which 54% was from marine fisheries, 21% from open freshwater fisheries, 19% from aquaculture and 6% from leasable freshwater fisheries (DoF, 2019). Including a hidden harvest estimate, total inland fisheries sub-sector landings within Myanmar could be around 1 million MT. This would rank Myanmar's inland fisheries production in 4th place globally behind China, India and Bangladesh (SOFIA 2020).

Myanmar ranks third out of 184 countries most affected by climate change in the last 20 years, (Global Climate Risk Index 2019). The National Disaster Management Committee states in the Myanmar Action Plan on Disaster Risk Reduction (2017) that Myanmar is one of the world's most disaster-prone countries, exposed to multiple hazards including floods, drought and cyclones. Poverty and poor infrastructure exacerbate its vulnerability to these hazards. To address the challenges the country is anticipated to face regarding climate change, the Myanmar government developed a National Adaptation Plan of Action (NAPA) in 2012. To address some of the barriers the Government of Myanmar (GoM) may face in the implementation of NAPA objectives (particularly regarding the fisheries sector) the Fisheries and Agricultural Organisation (FAO) managed FishAdapt project was developed.

Under the auspices of the FishAdapt project a letter of agreement (LoA) between WorldFish and the FAO was developed to conduct a risk assessment of the fisheries sector in Ayeyarwady region, Yangon region and Rakhine state. The risk assessment was divided into three distinct sub-sectors: 1) aquaculture; 2) inland fisheries and 3) coastal fisheries, representing the full extent of the fisheries sector throughout the study area. The risk assessment methodology presented within this report utilised the International Panel for Climate Change (IPCC) 2014 risk assessment framework. This shows that the risk of impact from climatic and non-climatic hazards is caused by the interaction of hazard, exposure and vulnerability. Within the context of this report, use of the 2014 framework provides managers with a unique opportunity to understand the drivers behind vulnerability within the fisheries and aquaculture sector, based on the integration of key indicators that influence the sub-sectors sensitivity and adaptive capacity. The inclusion of a futures model formed the basis for the generation of specific climate change adaptation policies for the fisheries and aquaculture sector and enabled, enabling uncertainties in future climate variability, climatic effects on fisheries and future socio-economic conditions in Myanmar to be overcome.

The report is divided into 4 main sections starting with: 1) introduction to Myanmar (describing climate change issues in the country, a description of the fisheries sector and a profile of the study area); 2) methodology (outlining in detail the four-step process used to conduct the assessment); 3) results (outlining current and future scenarios for the 3 sub-sectors across the 3 states and region) and 4) discussion and recommendations using 3 sections to outline i) model limitations and mitigations, ii) the interpretation of model outputs, and iii) mechanisms to reduce risk.

Introduction

Fisheries in Myanmar: A Brief Overview

Myanmar has a surface area of 676,578km^2 (of which 23,070km^2 is water) making it the second largest country in the Southeast Asia region behind Indonesia. The coastline is 1950km long with around 25,000 registered fishing vessels. Fisheries and aquaculture are important sub-sectors in Myanmar. According to the Department of Fisheries (DoF) statistics, the total production of fish in 2018[1] was 5,877,000 MT, of which 54% was from marine fisheries, 21% from open freshwater fisheries, 19% from aquaculture and 6% from leasable freshwater fisheries (DoF, 2019). Aquaculture ponds cover a total area of 491,345 acres and produced 1.1 million MT in 2019. The main aquaculture producing regions within the country are Ayeyarwady region and Yangon region (which focus on both fish and shrimp ponds) and Rakhine state (where almost exclusively shrimp ponds are registered). There are 3,342 leasable fishing areas in the country, producing approximately 341,000 MT per annum. Additionally, open fisheries have a production rate of 549,000 MT per annum, bringing total freshwater fisheries production to 890,000 MT. In the WorldBank report on capture fisheries (Kelleher *et al.,* 2012), it was shown that over half of the total fish catch in developing countries comes from the small-scale fisheries sub-sector. Even though recent assessments have suggested inland capture fisheries generate around a third of the tonnage recorded in the annual statistics, there is evidence of a considerable "hidden harvest" (i.e. unrecorded landings), which in the case of Myanmar's inland fisheries may be as high as 200,000 MT per annum. If the latter is correct, the total inland fisheries sub-sector landings within Myanmar could be around 1 million MT. This would rank Myanmar in 4th place globally behind China, India and Bangladesh (SOFIA 2020).

Fish is an important export product for Myanmar, with 568,227 tonnes of fish exported in 2017-18 for a total value of 712 million US$. The most important exported species are rohu, mud crab, ribbon fish and hilsa. Fishmeal is also an important export product, coming in fourth in terms of tonnage and export earnings. China and Thailand are the main destinations for Myanmar's fish exports. However, fish is not only important as an export product but also as a source of food on the domestic market; acting as the second most important food item after rice. Estimates by the DoF for 2017-2018 show that fish supply is 66kg/capita (this value was estimated by taking the total fish production in the country and subtracting exports and non-food uses). This is a significant increase in fish consumption from 2010, where reports by Belton *et al.* (2016) estimated fish consumption of 21kg per capita, based on household survey data. The real per capita consumption figure is between the two. Despite significant improvements in per capita fish consumption rates, there is large disparity in fish availability across social classes and geographic locations. Many low-income households have limited

[1] With the exception of the aquaculture figures (1.1 M MT) these have been revised downwards by the latest FAO reporting (SOFIA 2020) to a total of 3.13 M MT (aquaculture 1.1 M MT (35% total) freshwater capture 0.89 and M MT and marine 1.14 M MT).
http://www.fao.org/documents/card/en/c/ca9229en

access to protein sources and instead subsist on a nutrient deficient diet primarily comprised of rice (Dubois *et al.* 2019). In addition to the importance of the sector to human nutrition, fisheries act as the primary livelihood for 15 million people within Myanmar (Khin *et al.* 2020). With around 3.2 million people engaging in capture fisheries or aquaculture full-time (DoF, 2015).

Problem Statement

From 1998-2018 Myanmar ranked the second highest country in terms of climate change effects by the Climate Risk Index 2020 developed by GermanWatch (GermanWatch 2020). The climate within the country is already changing, with field measurements from 19 weather stations demonstrating an average temperature increase of 0.25°C between 1981 and 2010 (WWF 2017). Inland areas have seen a faster increase than coastal areas and the daily maxima has increased more than the daily average temperature. Direct effects of temperature increase on the fisheries sector are already being seen. With WorldFish documenting reduced oxygen saturation resulting in increased fish mortalities in May 2019 following fishpond surface temperatures of 36°C and 32°C at 2.5 m depth, (Lebel 2020). Rainfall patterns are also changing, with coastal areas seeing an increase in annual rainfall, spread out across the year; whereas in inland areas there has been more rain during the monsoon season. Additionally, a study by Lwin (2002) suggests the summer monsoon has shortened by one week.

Projections for the coming decades show that the increasing temperature trend will continue, with an estimated rise of 1.3°-2.7°C by 2050 (WorldClim 2020). There will also be an increase in extreme heat days of up to 17 days per year (in the period 1981-2010 there was on average only 1 extreme heat day per year). Additionally, a significant increase in rainfall during the monsoon and in sea level rise is anticipated to take place before the middle of the 21st century (WWF 2017).

To address the challenges the country is anticipated to face regarding climate change, the Myanmar government developed a National Adaptation Plan of Action (NAPA) in 2012. To address some of the barriers the Government of Myanmar (GoM) may face in the implementation of NAPA objectives (particularly regarding the fisheries sector) the FishAdapt project was developed (managed by the Food and Agricultural Organisation of the United Nations (FAO) and jointly funded by the Least Developed Countries Fund (LDCF[2]) of the Global Environment Facility (GEF)). A number of issues were identified as key barriers to climate change adaptation, these included:

- A lack of resilient sector policies and integration with fisheries specific international climate change policies.

[2] The Least Developed Countries Fund (LDCF) was established in 2001 to support the LDC work programme under the UN Framework Convention on Climate Change (UNFCCC), including the preparation and implementation of national adaptation programme of action (NAPAs). It is operated by the Global Environment Facility (GEF).

- A lack of capacity and resources for communities to plan for and adapt to the effects of climate change.
- Limited knowledge sharing and communication within the fisheries sector.

Overview of the Climate Based Risk Assessment within Myanmar

The FishAdapt project aims to assist the government and other stakeholders in the fisheries sector[3] to adapt to climate change by assessing current vulnerabilities, from community to national/sector levels. To assess vulnerability, a letter of agreement between WorldFish and the FAO has been developed to conduct a risk assessment of the fisheries sector in Myanmar. This includes the development and piloting of a methodology that can assist in the generation of adaptation methods and technologies along with information sharing. The goals of the project delivered through four components are as follows:

1. Develop and apply new adaptation techniques aimed at improving the resilience of the fisheries sector to climate change.
2. Demonstrate adaptation practices in vulnerable regions and communities.
3. Strengthen regulatory and policy frameworks.
4. Scale up adaptation techniques to include monitoring, evaluation and capacity building.

The present report, outlines a risk assessment of the fisheries and aquaculture sector, developed for Ayeyarwady region, Yangon region and Rakhine state (Figure 1). The framework (and associated methodology) is flexible, evidence-based and replicable – which could easily be scaled to/ implemented in other regions and states. As such, the GoM should be able to apply the methodology to assess the risk of the fisheries and aquaculture sector to key climate and non-climate hazards on a broader national scale. This will allow the government to develop more specific policies, targeting explicit regions or sub-sectors that have a higher relative risk of being impacted by hazards than others.

The risk assessment was divided into three distinct sub-sectors: 1) aquaculture; 2) inland fisheries and 3) coastal fisheries, representing the full extent of the fisheries sector throughout the study area. Across the study area, the three different states and regions (i.e. Ayeyarwady, Yangon and Rakhine) exhibited a different reliance on, and extent of, these fisheries sub-sectors.

[3] The capture fisheries and aquaculture sub-sectors are being stressed by several factors, of which climate change is clearly an important driver, although, increased pressure on the fisheries e.g., through Illegal, Unreported (technically speaking all the catches are unreported) and Unregulated (IUU) fishing as well as a number of associated factors such as destructive fishing methods (electric gears, poisoning, etc) should not be underestimated.

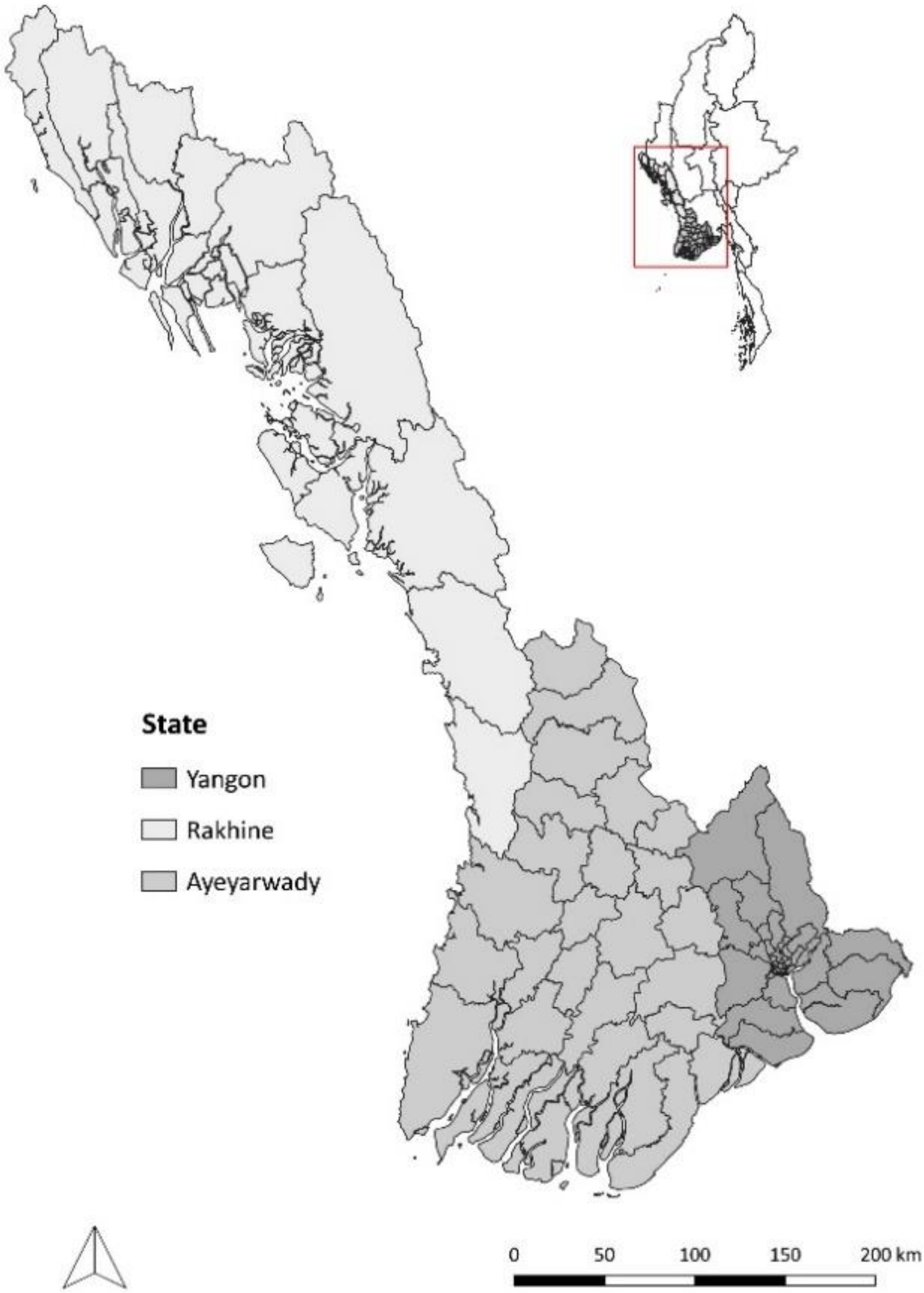


Figure 1: The study area of the climate-based risk assessment within Myanmar, including Ayeyarwady region, Yangon region and Rakhine state.

Ayeyarwady Region

Ayeyarwady region is in the delta of the Ayeyarwady river in lower Myanmar (Figure 2). The region is bordered by Yangon region to the east, Bago region to the northeast and Rakhine state to the northwest. The total population of the region (obtained during the 2014 census) was 6,184,829 people, of which 51% were women. Ayeyarwady region has a surface area of 35,964 km^2 and is divided into 26 townships. The region capital is Pathein. The region is mainly classified as a rural area, with 14 out of 100 people living in designated urban areas.

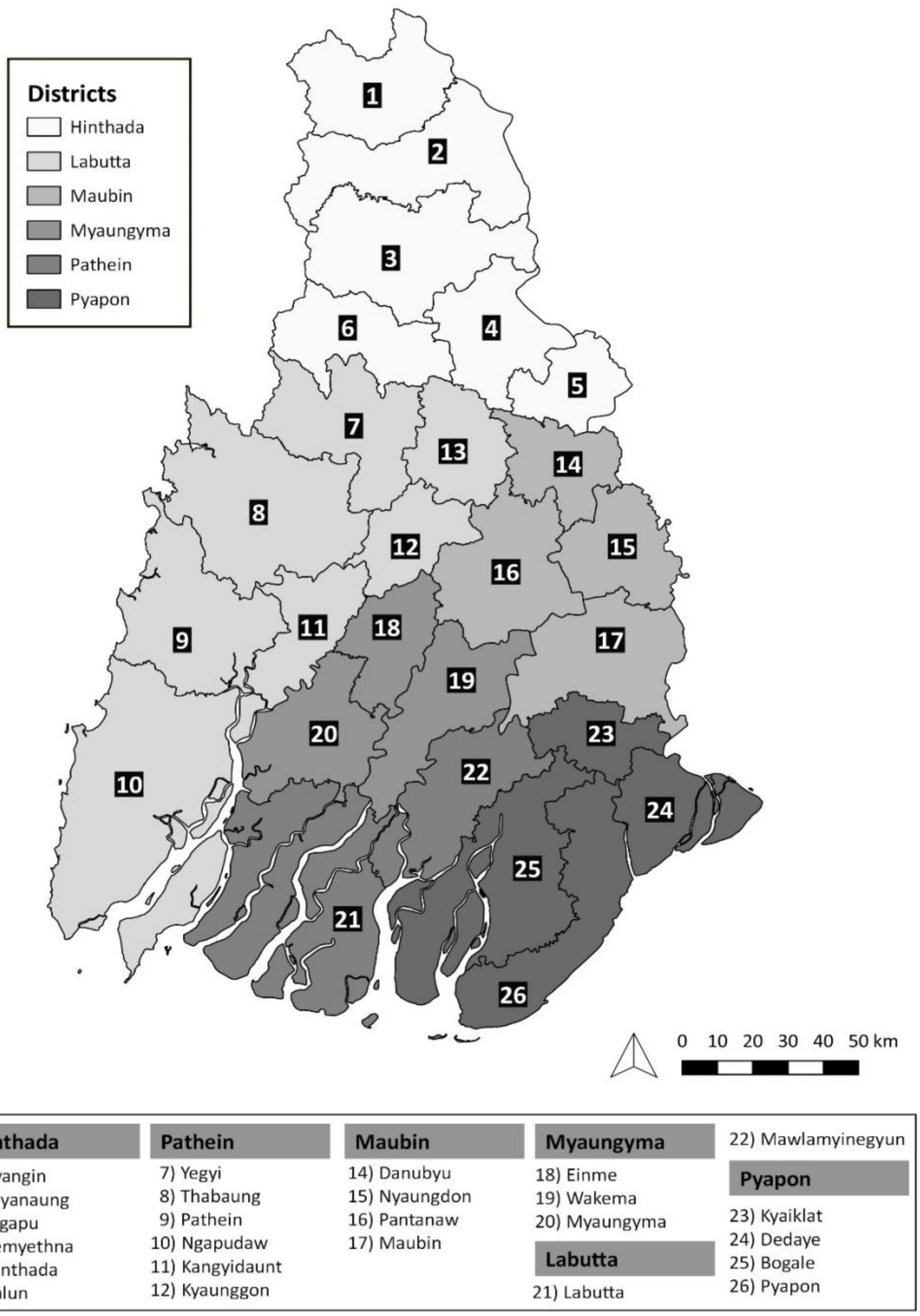


Figure 2: Map of Ayeyarwady region, showing the districts and townships in the area.

Agriculture, fishing and forestry are the most important sectors in Ayeyarwady in terms of employment; with 65% of the regions' population (aged 16 and over) stating that they work within these sectors. This is demonstrated by male employment statistics, where agriculture, fishing and forestry represents 70.6% of the workforce, for women this number is 55%. Ayeyarwady is particularly important in terms of its rice production, contributing to 28% of the total sown paddy area and production in Myanmar in 2016-17 (CSO 2018; Eurocham 2019). Within Myanmar, Ayeyarwady is the most important region for inland fisheries production; producing 47% of the total open and leasable fisheries production for the country in 2016-17 (727,486 tonnes). Additionally, aquaculture production within the region represented 49% of the country's total for 2016-17 at 502,932 tonnes (CSO 2018[4]). The region boasts the highest acreage for fishponds (121,811 acres), nearly double that of Yangon (the second highest region at 67,038 acres).

Yangon Region Yangon is in the heart of lower Myanmar and is bordered by Ayeyarwady to the west and Bago to the north and east (Figure 3). Yangon boasted a population of 7,360,703 people in 2014, 52% of which were women. Yangon is the most populated region in the country (with a population density of 716 inhabitants per km^2) and is the economic capital. The surface area of Yangon is 10,277 km^2. It is one of the most urbanised areas in the country, with 70% of the population living within the inner and outer city.

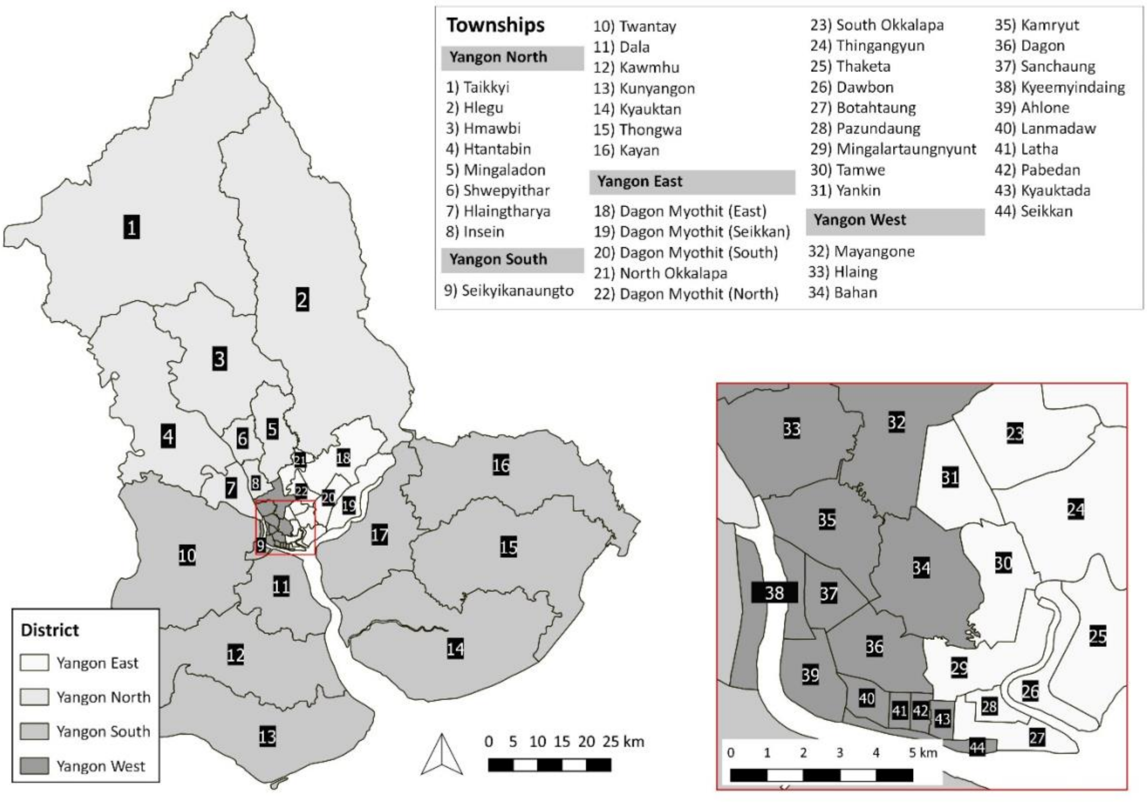


Figure 3: Map of Yangon region, showing the districts and townships in the area.

4 https://www.csostat.gov.mm/PublicationAndRelease/MyanAgriculture

Wholesale retail and trade are the biggest sectors in terms of employment in Yangon region, employing 15.8% of the total workforce. Manufacturing and agriculture, forestry, and fishing are second and third respectively, representing 14.8% and 14.7% of the workforce. However, when disaggregated by sex, agriculture, forestry and fishing are the most important sectors in terms of employment, especially for men at 18.6%. Inland fisheries in Yangon have a relatively high production compared to other states and regions; with open and leasable fisheries producing 81,902 tonnes in 2016-17. Additionally, Yangon is the second highest producing region for aquaculture. Across the region there are 4,2848 registered aquaculture ponds with a total surface area of 67,038 acres.

Rakhine State

Rakhine State is in the west of Myanmar and is bordered to the west by Bangladesh, by Chin State to the northeast, Magway to the east, and Bago and Ayeyarwady to the southeast. The Arakan Yoma mountains form a natural border to states bordering to the east. Rakhine had a total population of 3,188,807 people during the 2014 census. However, not every household in Rakhine was enumerated, so an estimate of around 1,900,000 people was added to enumerated households (2,098,807), reaching a total of slightly over 3,000,000 individuals. Males represented around 48% of the population. The total surface area of Rakhine is 36,778 km². The state is divided into 16 townships, and the state capital is Sittwe. Rakhine is a mainly rural area, with few people (17/100) living in urban environments (Figure 4).

The agriculture, forestry and fishing sectors are important within Rakhine, representing around 52% of the total workforce. Aquaculture is the most important fisheries sub-sector within the state, with a total production of 31,208 tonnes in 2016-17. Aquaculture installations within Rakhine are primarily shrimp culture, with a total surface area of 156,489 acres, representing 65% of all shrimp ponds throughout Myanmar. Inland fisheries have a much lower production rate (10,656 tonnes in 2016-17). Marine and coastal fisheries are important within Rakhine, which has one of the main fish landing sites at Thandwe township. The area is one of the three main coastal fishing zones in Myanmar's waters. Fishers in the area target Penaeid shrimp and anchovies using bottom trawls and anchovy purse seine respectively (FAO 2019).

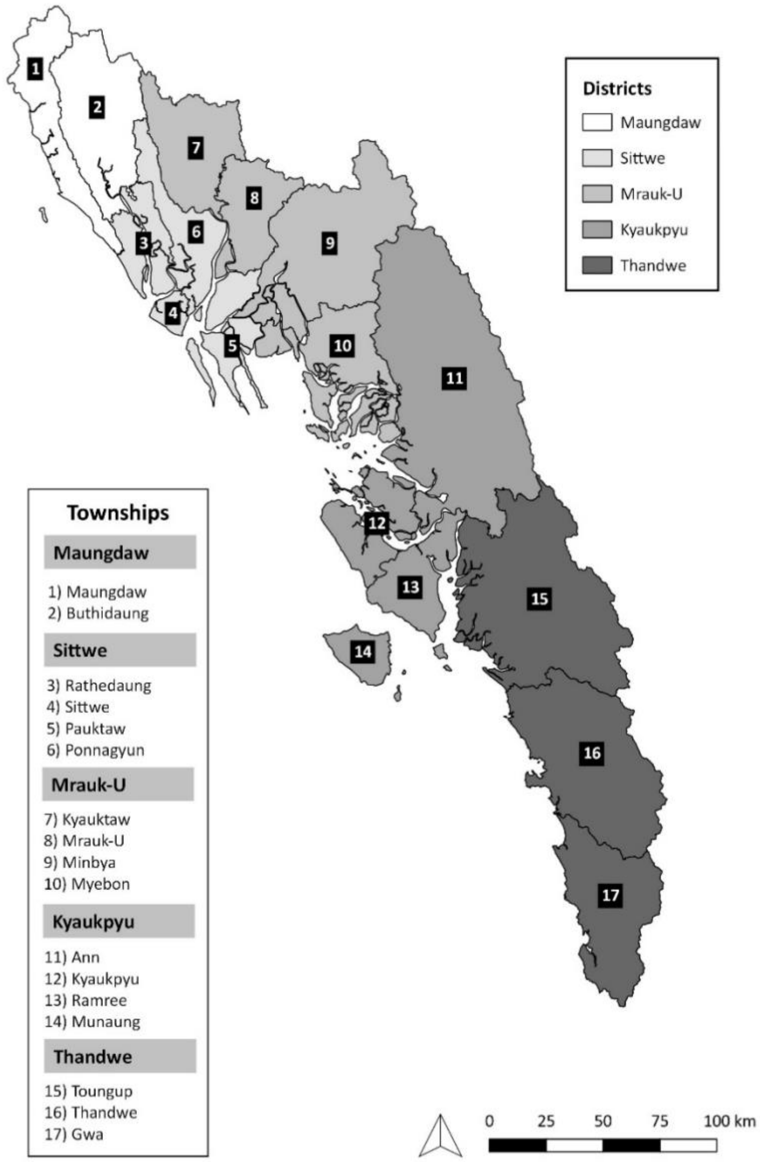


Figure 4: Map of Rakhine state, showing the districts and townships within the area.

The 2014 IPCC Risk Assessment Framework

The risk assessment methodology presented within this report utilised the International Panel for Climate Change (IPCC) 2014 risk assessment framework. This shows that the risk of impact from climatic and non-climatic hazards is caused by the interaction of hazard, exposure and vulnerability. This is a next generation framework that builds upon the more widely implemented 2007 methodology (IPCC 2007). The 2014 framework defines vulnerability as a system's "propensity or predisposition to be adversely affected" by exposure to a hazard and considers "hazard-relevant" indicators which reflect the system's sensitivity and adaptive capacity. The model comprises three main components that combine to determine risk (R): (1) Hazard (H); (2) Exposure (E); and (3) Vulnerability (V). The vulnerability of a system (i.e.

fishery) is further assessed by determining (3a) Sensitivity (S); (3b) Adaptive Capacity (AC) as sub-components (Figure 5).

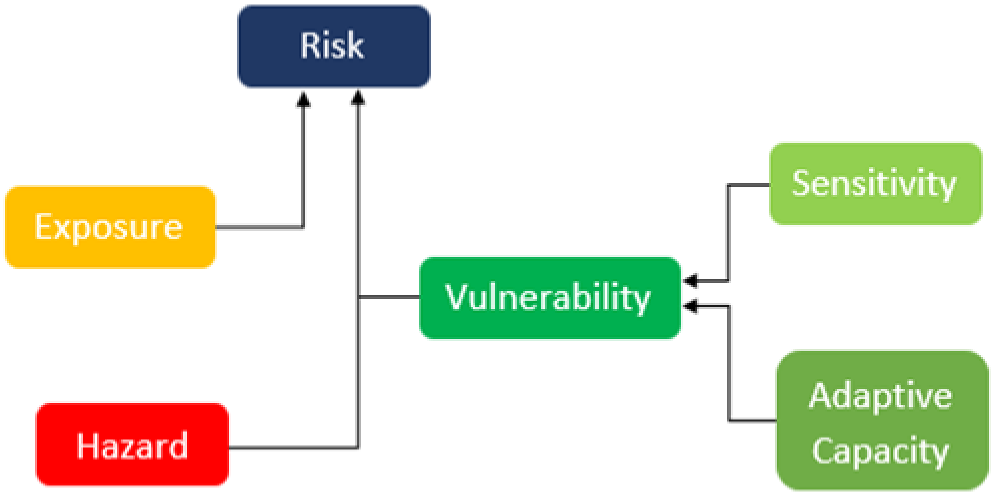


Figure 5: The IPCC (2014) risk assessment framework.

The terminology used to describe the risk and its components is presented in Table 1.

Table 1: Terminology used to describe risk (and its sub-components) within the IPCC (2014) risk assessment framework.

Risk (R)	**The** potential for consequences **where** something of value **(i.e. fisheries) is** at stake **and where the** outcome is uncertain, **recognising the diversity of values. Often represented as the probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.**
Hazard (H)	The potential occurrence of a **natural** or **human-induced physical event** or **trend** or **physical impact** that may cause loss of life, injury or other health impacts as well as damage and loss to property, infrastructure, livelihoods, service provisions, ecosystems and environmental resources.
Exposure (E)	The **presence** of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure or economic, social or cultural assets **in places and settings that could be adversely affected**.
Vulnerability (V)	The **propensity or predisposition to be adversely affected**. Encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Sensitivity (S)	**Degree** to which **a system** (i.e. fishery) is directly or indirectly **affected**, either adversely or beneficially **by climate variability or change.**
Adaptive Capacity (AC)	The **ability** of a system/institution/humans/other organisms to **adjust to potential damage** and to take advantage of opportunities or respond to consequences.

The primary difference between the 2007 and 2014 iterations of the framework regards the conceptualisation of vulnerability. Within the 2014 framework, vulnerability is considered as a pre-existing contextual state of the system (O'Brien *et al.* 2007). As such, it is a characteristic internal property and not directly associated with the systems' exposure to a hazard, but is addressed in the context of "hazard-relevant" indicators for sensitivity and adaptive capacity that will affect the systems' ability to cope with an anticipated hazard (Sharma *et al.* 2013). Vulnerability within the 2014 framework therefore assesses the weaknesses within a system and the capacity of the system to deal with the negative impacts from exposure to a hazard (Sharma *et al.* 2019). This significantly contrasts to the 2007 conceptualisation, where vulnerability was assessed in terms of the adverse impact that resulted following a systems exposure to a hazard (Figure 6) (Jurgilevich *et al.* 2017).

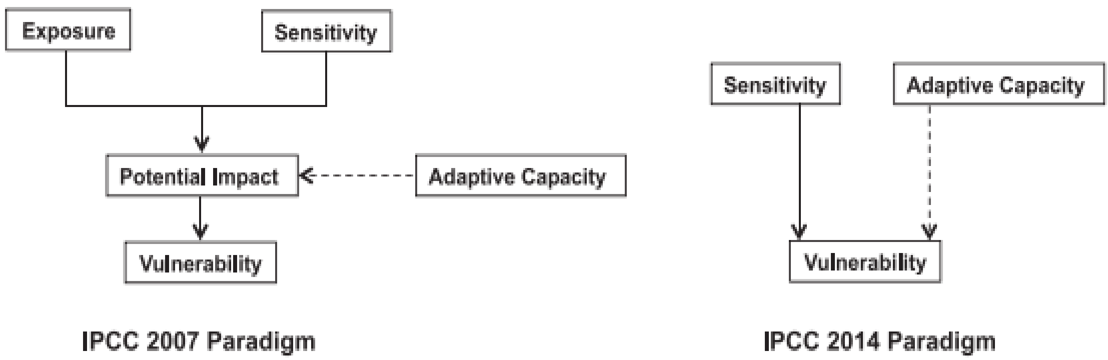


Figure 6: The conceptualisation of vulnerability within the IPCC (2007) and IPCC (2014) risk assessment frameworks.

The utilisation of the 2014 framework within this report offers a more practically useful analysis of vulnerability; allowing model outputs to be interpreted in a manner that facilitates the identification of the drivers behind vulnerability. This enables managers to develop mitigation strategies that can reduce the vulnerability of a system by addressing identified drivers. Such mitigation strategies thereby reduce the potential risk of a system to be impacted by hazards.

As vulnerability is considered in anticipation of a hazard (instead of following a hazard), the framework additionally provides an opportunity to assess the current status of a system and reflect the manner in which it may be impacted by future hazards, including climate change (Sharma *et al.* 2019). This enables pre-emptive adaptation measures to be implemented based on present drivers of vulnerability, which can act to mitigate against predicted future impacts for a given system. The framework takes this one step further by enabling estimations of the future extent and impact of a hazard to be incorporated into the overall assessment of risk within a system. As such, where a risk assessment occurs over a large spatial scale, the model enables the identification of areas of potential high impact from future hazards alongside drivers of vulnerability. This provides managers with the ability to prioritise specific locations within a system where future impacts will be intermediate. The resilience of a system to a future hazard can therefore be strengthened by implementing adaptation measures regarding vulnerability.

Within the context of this report, use of the 2014 framework provides managers with a unique opportunity to understand the drivers behind vulnerability within the fisheries and aquaculture sector, based on the integration of key indicators that influence the sectors sensitivity and adaptive capacity. Additionally, the inclusion of a futures model within the report forms the basis for the generation of specific climate change adaptation policies for the fisheries and aquaculture sector and enables uncertainties in future climate variability, climatic effects on fisheries and future socio-economic conditions in Myanmar to be overcome. Finally, as most studies continue to use the IPCC 2007 definition of vulnerability, this report provides a significant contribution to the wider risk assessment literature.

Fishers return home with catch from Maubin floodplain, Ayeyarwady Region.

Methodology

The methodology presented below was developed to align with the most recent developments in IPCC (2014) thinking on vulnerability and risk and in order to be replicable, with a view to scaling e.g., by the Government of Myanmar.

Step 1: Contextual Analysis

Step 1: Overview

- **Review of in-country and/or in-region climate impact assessments** conducted for fisheries and aquaculture.
- **Development of selected risk assessment framework** (including methods and tools for framework application).

Review of Climate Impact Assessments

To select the methodological approach for the risk assessment an in-depth literature review was conducted in June 2019. This assessed publications that provided an overview of risk assessment concepts and methodologies in the context of fisheries. The assessed publications were selected using a list of criteria that was compiled with inputs from various experts on Myanmar and on the fisheries sector. There were 43 criteria, grouped under 8 categories. (See Annex 1 for an overview of the methodology used for the review). Additionally, pros and cons of risk assessment methodologies were listed to highlight the overall approach, the framework used and features that make each method unique.

Framework Development

Following the literature review, the framework developed by the IPCC in their (AR5) 2014 report was selected for the following study and adapted by WorldFish to fit within the context of the fisheries sector in Myanmar.

Step 2: Agenda Setting

Step 2: Agenda Setting

- **Determining risk assessment priorities** through multi-level stakeholder consultation workshops.
- **Selecting model scenarios** using information from stakeholder consultations and an overview of data availability.
- **Selecting indicators to represent risk and its components** through multi-level stakeholder consultation workshops.

Determining Risk Assessment Priorities

Multi-level stakeholder consultations were held in September 2019 to determine climate change risk assessment priorities based on participants knowledge of contextual vulnerability within Myanmar and experiences from policy level and field work at the national and regional level and from a sectoral perspective. During the consultations, priority was given to understanding the government's strategic development plans within the fisheries and aquaculture sector and how these may be vulnerable to, or used as mitigation measures to climatic variability and change. Consultation workshops were attended by members of the following government departments: Irrigation and Water Utilisation Management Department (IWUMD), General Administration Department (GAD), Department of Rural Development (DRD), Department of Fisheries (DoF), Department of Agriculture (DoA) and Department of Agricultural Land Management and Statistics (DALMS).

Scenario Selection

The following model assesses present (2020) and future (2040) risk to the fisheries sector of Myanmar given key hazards that exist within the study area, comprising Ayeyarwady and Yangon region and Rakhine state. The fisheries sector was split into three sub-sectors that drive overall fisheries productivity within Myanmar: (1) aquaculture; (2) inland fisheries and (3) coastal fisheries. To most accurately determine the overall risk level of these sub-sectors the model was run based on a number of 'scenarios'. This led to the generation of individual outputs for each sub-sector and timeframe (i.e. present or future) resulting in a total of 6 model iterations.

The selection process for the date of the futures scenario (i.e. 2040) was based on data availability and clarity. Specifically, it was decided that a 'near future' scenario would be most appropriate given the significant decrease in the accuracy of predictions of future climatic conditions in the more distant future (e.g. 2100). Furthermore, given the rapidly shifting social and economic context within Myanmar, it is difficult to predict the future status of risk components including exposure, sensitivity and adaptive capacity. As such, selecting a near futures scenario increased the validity of the futures' model both in terms of the data utilised in its generation, and in the ability to accurately interpret outputs based on available qualitative information of Myanmar's future context (i.e. predictive environmental and socioeconomic reports including the National Adaptation Plan of Action (NAPA 2012) and Agricultural Development Strategy (ADS 2018).

Indicator Selection Process

The IPCC (2014) risk assessment framework is an indicator-based model. The use of indicators allows for a high degree of flexibility, with numerous variables often able to represent the same indicator. This is useful within the context of this study given the variability in the robustness and extent of different variables that could analogously represent the same indicator (e.g. extent of aquaculture ponds could be represented via pond area, pond size, or number of facilities). The use of an indicator-based model therefore enables multiple variables to be analysed and filtered for missing data, outliers etc., and the variable selected that most accurately reflects the state of an indicator.

Multi-Level Stakeholder Consultation Workshops

The first step in the development of the risk assessment model comprised the identification of indicators that reflect the key factors that influence the frameworks' components (i.e. what hazards exist within the study area). Indicator selection took place using a multi-stage participatory approach, comprising a series of consultation workshops with local government stakeholders. Given the restrictions placed on participatory research by COVID-19, stakeholder consultations were limited to two individual workshops; these took place on the $24^{th}/25^{th}$ February in Yangon, and the $3^{rd}/4^{th}$ March (2020) in Pathein district in the Ayeyarwady delta. Workshops were attended by key representatives from the Department of Fisheries (DoF); Forestry Department (FD); Department of Rural Development (DRD); Department of Disaster Risk Reduction (DDRR); Irrigation & Water Utilisation Management Department (IWUMD) and the Department of Agricultural Land Management & Statistics (DALMS). These representatives were invited to attend by WorldFish and FAO based on their knowledge of, and involvement within, the fisheries sector and/or sectors that directly influence fisheries.

Workshops were separated into two key exercises:

Exercise 1: The first exercise comprised the identification and selection of indicators for each individual risk component (e.g. E, H, S, AC). This exercise was preceded by an overview of the IPCC (2014) methodology and the terminology used within the risk assessment framework, to aid in participants' understanding of the potential indicators that may comprise each component. Given the variable expertise of workshop participants, the exercise was divided into two break-out groups (aquaculture and wild capture (i.e. inland and coastal) fisheries), determined by participants' knowledge of a given fisheries sector. Upon completion of the exercise, the indicator lists were presented to the overall group, allowing for further discussion and refinement.

Exercise 2: Upon final selection of an indicator list for the hazard component of the framework, participants were asked to individually rank the relative impact they considered each hazard to have on (1) aquaculture; (2) inland fisheries and (3) coastal fisheries. To do so, participants were asked to use their expert knowledge to consider the relative prevalence of a hazard and its relative impact on a given sub-sector in relation to the other indicators within the list. Each participant had to give what they thought were the three most important hazards. The number one hazard was scored 3, the second hazard was scored 2, and the third hazard received a score of 1. To obtain final hazard ranks for input into the risk assessment model, individual ranking scores were combined and an average rank for each hazard generated. The final list of indicator (for model inclusion) that were selected by participants is shown in Table 2. The indicator list (and hazard ranks) developed during the first workshop in Yangon was validated during the second workshop in Pathein, where additional indicators were added (or removed). The final indicator list and hazard ranks were based on the consensus result from the two groups.

Table 2: The indicator list (by risk component) determined by participants during multi-level stakeholder consultation workshops.

RISK COMPONENT INDICATOR			
HAZARD			
1	Flooding	**7**	Infrastructure development
2	Drought	**8**	Changes in agricultural systems
3	Deforestation	**9**	Water pollution
4	Storms	**10**	Dam construction
5	Temperature Increase	**11**	Forest area demarcated as PPA
6	Sea level rise	**12**	Groundwater level increase
EXPOSURE			
1	Population density	**4**	Agricultural land
2	Infrastructure	**5**	Economic Infrastructure
3	Fishing grounds		
SENSITIVITY			
1	Income	**6**	Labour migration
2	Employment	**7**	Fish market price
3	Fish production	**8**	Water supply
4	Fish disease	**9**	Market Links
5	Pond size	**10**	Tax revenue from fisheries (contributing to GDP)
ADAPTIVE CAPACITY			
1	Access to financial services	**7**	Accessibility (ports)
2	Community development fund	**8**	Mangrove rehabilitation
3	Access to markets	**9**	Conservation zones
4	Education level	**10**	Emergency disaster fund
5	Capacity development	**11**	Emergency warning system
6	Accessibility (roads)	**12**	Alternative livelihood diversity

Selecting Indicator Variables

The indicators obtained from the participatory workshops provided the basis of the variable selection process. This involved the identification of any quantitative variable that could be used to represent a given indicator (e.g. extent of aquaculture ponds could be represented via pond area, pond size, or number of facilities). Where possible, variables were selected that would directly represent a specific indicator (e.g. pond area); however, where this data was likely not available (or where no direct measurement existed) a proxy was used in its place (e.g. number of aquaculture facilities). Quantitative variables were selected based on expert knowledge and an extensive search of literature that was applicable to the context of a given indicator. Where possible, this included consulting variables used to qualitatively measure analogous indicators within previous risk assessments.

Indicating Future Risk

Within Myanmar, models do not exist that quantitatively predict future indicators of exposure, sensitivity and adaptive capacity. As such, the futures scenario only acts to differentially predict differences in climatic conditions between 2020-2040. Results from the futures' scenarios therefore predict the response of the fisheries sector to more extreme climatic conditions (reflective of the IPCC's "middle of the road" socioeconomic pathway (e.g. RCP4.5)) given present day infrastructure and socioeconomic conditions.

Step 3: Data Collection and Quality Checks

Step 3: Data Collection & Quality Check

- **Collect primary data from government offices** during field visits to Ayeyarwady region (Rakhine and Yangon data collection was restricted by COVID-19, and therefore district and regional heads were contacted and provided that data electronically or sometimes taking photographs of paper based data.
- **Collect secondary data** from internet searches and the head offices of government departments.
- **Data compilation** within excel and **validity checks** for data errors, missing values and outliers.

Secondary Data from Government Departments

Prior to the COVID-19 outbreak secondary data was collected in person from township and district offices in the Ayeyarwady Delta. Later restrictions placed on travel prevented field visits to these offices, particularly due to the distance, those in Rakhine. This was largely ameliorated by directly consulting the head offices of departments that had collected data on previously selected variables, but one or two variables had to be dropped as a result.

Secondary Data from Online Sources

To supplement primary data collection, an extensive internet search was conducted to collect additional datasets on selected variables. To assure data quality and consistency, internet

Selecting the Scope: Determining the Administrative Level of the Model

The data collection process facilitated the selection of the scope (or administrative level) of the study. This had previously been omitted from detailed discussion given its fundamental dependence upon the availability of data that represented selected indicators. From a provisional search into data availability, it was quickly determined that the majority of accessed datasets were recorded at the township level, defining the scope of the model. All data was thus recorded at this administrative level. Correspondingly, data was collected for a total of 87 townships across the study area (Ayeyarwady (n=26); Rakhine (n=17); Yangon (n=44). Townships were defined using MIMU's 2019 administrative boundaries.

(**A number of townships within the study area were excluded from the model given a specific circumstance that made a township irrelevant to the context of the study (i.e. Cocokyun)).*

searches were restricted to the websites and annual reports of government departments and MIMU. Additionally, climatic variables (comprising hazard indicators) were obtained from widely recognised and reputable sources that have commonly been utilised within climatic studies.

Data Compilation and Validity Checks

The collated datasets were transcribed into MS Excel, producing an extensive quantitative database of variables that represented risk component indicators. The database was correspondingly filtered for missing values and validity using the R statistical programming language, REF XX. This process led to the elimination of any variable where data errors and/or missing values comprised >5% of the data. Following this filtration process, the database was additionally screened for outliers. Where outliers significantly skewed data for a given variable, the identified outlier values were excluded. The thorough nature of the data analysis process enabled a single variable (comprising robust data) to be selected to represent each indicator.

Step 4: Model Construction

Step 4: Model Construction

- **Data based selection of indicators and proxy variables.**
- **Quantification and normalisation of indicators.**
- **Assign weights to indicators** using the Analytic Hierarchy Process
- **Aggregation of weighted indicators** into hazard index, exposure index, vulnerability sub-indices and overall RISK index.
- **Analysis of model results and assignment of priority/ranks of risk level.**

Data Based Selection of Indicators and Proxy Variables

The final list of indicators (and the proxy variables used to represent them) is exemplified below. These indicators were selected from within the broader risk assessment database. On occasion an indicator that was selected by participants in the preliminary consultation workshop could not be represented due to a lack of appropriate data; where this occurred, the indicator was excluded from the model. The following tables provide information on the proxy variable used to represent each indicator, an interpretation of the manner in which this variable contributes to each risk component and the metadata associated with the data comprising each variable.

Hazard

From a preliminary list of twelve hazard indicators, six were included within the model. These were: (1) river flooding and (2) storms (represented by the total estimated flooded area within a township based on past events); (3) temperature increase over time; (4) drought extent (based on the number of months a township was subjected to drought conditions); (5)

deforestation over time and (6) sea level rise (represented by the area inundated if a 1m rise in sea level occurred (Table 3). It should be noted that the hazards and their relative importance included within the model were based on results of the stakeholder consultation workshops - and their variables, based upon the availability of data. Differentiating between climate variability and change and between climate change and resource management impacts is also data dependent.

Table 3: The variables used to represent indicators for the hazard component of the risk assessment considering present (PS) and future (FS) scenarios.

HAZARD						
Indicator		**Variable**	**Interpretation**	**Unit**	**Source**	**Year**
1	Flood	Total flooded area from river floods	Flooding can cause damage to aquaculture installations and will affect fisheries production and fishing activities.	m^2	MUDRA	(PS) 2019 (FS) 2040
2	Storm	Total flooded area from storm surges	Storms can cause damage to aquaculture installations, fishing boats and gears and lead to loss of human life.	m^2	MUDRA	(PS) 2019 (FS) 2040
3	Atmospheric temperature Increase	Increase in maximum temperature per annum	Increasing temperature can lead to a shift in species composition and natural habitats and increase stress and disease prevalence in aquaculture installations.	◦C	WorldClim	(PS) 2010-18 (FS) 2020-40
4	Drought	Number of months under drought conditions	Negatively impacts aquatic ecosystems and reduces stream flow, habitat quality and availability.	# of months	(PS) WASP (FS) SPEI	(PS) 1999-19 (FS) 2020-40
5	Deforestation	Cumulative area of forest loss	Deforestation (especially of mangroves) leads to a decrease in natural barriers against floods and storms.	km^2	Hansen	(PS)2000-19 (FS) n/a
6	Sea Level Rise	Area inundated by a 1m rise in sea level	Areas subjected to flooding and salinity intrusion will lead to decreased suitability for freshwater fisheries and aquaculture, but will provide opportunities for brackish-water aquaculture and coastal fisheries.	km^2	CReSIS	(PS) n/a (FS) 2040

Analysing Climatic Variables

Given the global nature of the databases selected for the representation of climatic variables, an additional step was required for analysis of this data. This step took the form of a data extraction process; enabling each climatic variable to be represented within the bounds of individual townships across the study area. The extraction process occurred within QGIS. Here, the MIMU (2019) township boundary shape file supported data extraction within the zonal statistics function. The exact process varied between variables given the differential nature of the file format (e.g. GeoTIFF and netCDF) for further information see Table 4; Annex 2.

Table 4: Analysis required in the use of climatic variables as hazard indicators.

Climatic Variable	Source	Unit	File Type	Spatial Resolution	Analysis using Zonal Statistics
Temperature Increase					
Present Scenario	WorldClim	°C	GeoTiff	21 km^2	Extraction of min/max temperature values (2010-18).
Future Scenario	WorldClim	°C	GeoTiff	21 km^2	Extraction of max temperature values (2020-40).
Drought					
Present Scenario	WASP	WASP Index	Net-CDF	55km^2	Index values converted to (1) wet (0) dry, and wet values extracted.
Future Scenario	SPEI	SPEI Index	Net-CDF	10km^2	Index values converted to (1) wet (0) dry, and wet values extracted.
Sea Level Rise					
Present Scenario	n/a	n/a	n/a	n/a	n/a
Future Scenario	CRESIS	Km^2	GeoTiff	1km^2	Sum of all inundation areas calculated.

Exposure

Variables selected for the exposure component of the risk assessment referred mostly to the geographical aspect of a given indicator. The majority of indicators selected during the consultation workshop were included within the model; however, infrastructure and economic infrastructure were combined. The four indicators included within the model were as follows: (1) population density; (2) fisheries infrastructure (represented by the economic risk posed by destructive hazards (i.e. floods and storms)); (3) agricultural land area (representing ecosystems and environmental functions as seasonal floodplains for capture fisheries and potential sources of fish feed for aquaculture) and (4) fishing grounds. As the variable for fishing grounds varied between wild capture and aquaculture, two were selected for this indicator. The number of fishing licences was used as a proxy measurement to represent the extent of fishing grounds for inland and coastal fisheries, whereas pond surface area was used to directly represent the extent of fishing grounds for the aquaculture sector (Table 5).

Table 5: The variables used to represent indicators for the exposure component of the risk assessment.

EXPOSURE						
Indicator		**Variable**	**Interpretation**	**Unit**	**Source**	**Year**
1	Population density	Number of people per km^2	The number of people exposed to a hazard (influencing demand and workforce).	km^2	MIMU	2019
2	Fisheries infrastructure	Economic risk to infrastructure based on storms and flood events	*Proxy measurement* The impact of destructive hazards on fisheries infrastructure based on economic evaluation.	Risk level	MUDRA	2010-18
3	Agricultural land	Surface area of agricultural land	Agricultural land can be utilised as a floodplain for capture fisheries or a source of fish feed for aquaculture.	Acres	LUD	2018-19
4	Fishing grounds	**a)** Number of fishing licences for wild capture fisheries.	*Proxy measurement* The extent of wild capture fishing grounds based on the number of licences (i.e. fishers).	# licences	DoF	2018-19
		b) Surface area of aquaculture ponds	The extent of the aquaculture sector based on the total surface area of ponds.	Acres	DoF	2018-19

Sensitivity

Sensitivity was the most poorly represented risk component within the model when comparing the utilised indicators with those selected within the consultation workshop. For this risk component, there were five indicators where no representative data could be found at the township level, these included income levels, fish disease, labour migration, fish market price and tax revenue from fisheries. The final indicators selected to represent the sensitivity of each sector were: (1) production; (2) employment; (3) irrigation; (4) fishing area and (5) fish seed supply. Only the first three indicators were applied to wild capture fisheries (i.e. the inland and coastal sectors). Production represented the nutritional, environmental and ecological aspect of each sector. Employment represented the economic importance of the sector. Irrigation infrastructure was included to represent its role in increased water supply and creation of aquatic habitats for aquaculture and capture fisheries. Pond surface area was included to represent the size of the sector in each particular township. Finally, hatcheries were used to represent fish seed supply to aquaculture facilities. Higher number of hatcheries within a township indicate a higher relative importance of the sector within an area (Table 6).

Table 6: The variables used to represent indicators for the sensitivity component of the risk assessment.

SENSITIVITY						
Indicator		**Variable**	**Interpretation**	**Unit**	**Source**	**Year**
1	Fisheries Production	**a)** Aquaculture production	The relative importance of the aquaculture sector to a township.	Viss	DoF	2018-19
		b) Inland fisheries production	The relative importance of inland fisheries to a township.	Viss	DoF	2018-19
		c) Coastal fisheries production	The relative importance of coastal fisheries to a township.	Viss	DoF	2018-19
2	Employment	Number of people dependent on fisheries as a livelihood	*Proxy measurement* for the relative importance of fisheries and aquaculture to employment within a given township.	# People	GAD	2019
3	Irrigation	Number of dams, weirs and sluices.	Infrastructure provides water to aquaculture installations, and in the provision of aquatic habitats.	IWUMD	# dams, weirs, sluices	2019
4	Fishing area *(*AQ only)*	Surface area of aquaculture ponds.	The relative importance the aquaculture sector within a township.	DoF	Acres	2017-18
5	Fish seed supply *(*AQ only)*	Number of hatcheries.	Aquaculture installations are dependent on a steady supply of high-quality fish seed.	DoF	# Facility	2019

Adaptive Capacity

The indicators chosen for adaptive capacity reflected the ability of the people and/or ecosystem to adapt, mitigate or reduce the negative effects of the identified hazards, thereby reducing the vulnerability of the system. The majority of indicators selected during the consultation workshops were included; however, no data existed that reflected emergency responses or conservation zones in detail. Indicators utilised within the model to reflect adaptive capacity included: (1) access to financial services, this was included to reflect the ability for higher access to credit or loans to mitigate the impact of reduced income from fisheries. (2) Market access, where a greater number of buyers or sellers generally had a positive influence on household income. (3) Education level represented the potential to diversify livelihoods; with higher-educated households usually subject to a greater number of livelihood options. (4) Capacity development was reflected by the number of DoA training sessions, and additionally reflected the potential for alternative livelihood options. Accessibility by (5) road and (6) ports and landing sites reflected the fact that better connectivity would make a township more capable of adapting quickly/more efficiently, as higher accessibility would give a township easier access to a wide range of services. (7) Community development in the form of Mya Sein Yaung projects, this represented the financial ability of each township to mitigate or adapt to a certain hazard. (8) Mangrove loss was included within adaptive capacity as it was interpreted that townships with a greater percentage of loss were more affected by hazards (Table 7).

Table 7: The variables used to represent indicators for the sensitivity component of the risk assessment.

ADAPTIVE CAPACITY						
Indicator		**Variable**	**Interpretation**	**Unit**	**Source**	**Year**
1	Access to financial services	Number of banks and microfinance providers	Access to financial services allows households to bridge periods with no/low income.	#	GAD	2019
2	Access to markets	Number of wet markets, fish traders and wholesalers	Greater flexibility in market choice strengthens the position of producers (fishers, aquaculture pond owners).	#	GAD	2019
3	Education level	Percentage of literate adults	Higher educated households plan against and adapt to the effects of hazards better,	%	MIMU	2019
4	Capacity development	Number of DoA training sessions	Capacity building in agriculture allows people in the fisheries sector to have alternative livelihood options.	#	DoA	2019
5	Accessibility (roads)	Length of main roads	Providing aquaculture/ fisheries with access to facilities and services.	Miles	MIMU	2019
6	Accessibility (ports/landing sites) *(WC only)*	Number of ports and landing sites	Providing fisheries with access to facilities and services.	#	GAD	2019
7	Community development fund *(WC only)*	Total budget for Mya Sein projects	Community funds can be used to implement adaptation measures, or rebuild infrastructure after a hazard.	MMK (millions)	GAD	2019
8	Mangrove loss *(WC only)*	Percentage loss of mangrove forests	Mangroves provide important ecosystem services to aquaculture and fisheries. Lower loss percentages allow communities to adapt more quickly.	GMW	%	1996-2016

Quantification & Normalisation of Indicators

Data for each variable were not measured in the same unit. As such, it was necessary to normalize (transform) the data into a comparable measure. For each variable, the transformation to an ordinal scale ranging from 0-100 was applied based on the lower and upper bounds of the data range. Here, it was assumed that the position of an individual score represented by a township was relative to the spread of the full range of an indicators' impact across the study area.

This transformation process enabled the relative effect of each indicator to be interpreted and compared within and across risk components. Where a township scored a high value, that indicators' impact was considered to be high, negatively effecting the overall risk score. For adaptive capacity, the opposite occurred, with a high value positively influencing (or reducing) overall risk. The reverse nature of the impact scale for adaptive capacity was addressed during the modelling process.

Indicator Weighting Using the Analytic Hierarchy Process

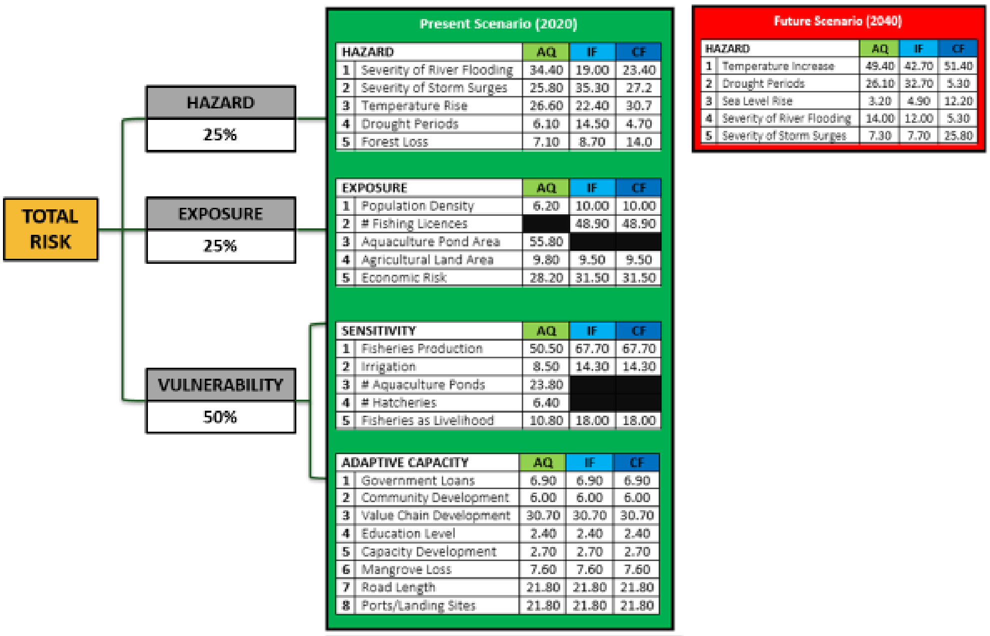
To reflect the relative importance of each indicator on the fisheries sector within its wider risk component (e.g. exposure of the human population versus fisheries infrastructure) a multi-criteria evaluation (MCE) of the transformed database was conducted. This took place using the Analytic Hierarchy Process (AHP) developed by Saaty (2008). This method of MCE has been extensively used when considering environmental issues.

The AHP process began via the development of a hierarchy of indicators, that could be analysed and compared. Once the hierarchy was developed, expert judgement (comprising a panel of experts) was used to make pair-wise comparisons based on the Saaty scale shown in (Table 8). This directly compared the relative effect of paired indicators on the fisheries sector. Using the Saaty scale, the expert panel scored relative effect on a scale from 1 (where each indicator had an analogous impact on fisheries) to 9 (where one indicator had a very high impact, and one indicator had a very low impact on fisheries). The AHP model then transformed the outcome of each pairwise comparison into a numerical weight. Following the completion of all pairwise comparisons, all indicators within the hierarchy were weighted against each other and a weighting matrix produced.

Table 8: The Saaty scale used to rank pairwise comparisons within the AHP process.

Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one element over another
5	Strong importance	Experience and judgement strongly favour one element over another
7	Very strong importance	One element is favoured very strongly over another, dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one element over another is of the highest possible order of affirmation
2,4,6,10	Intermediate values	When compromise is needed

To assess the reliability of the judgements made by the expert panel, a consistency ratio (CR) of pairwise comparisons was calculated. This measured the consistency of expert judgement between pairs, relative to a large sample of random judgements generated by the AHP model. If the CR exceeded 10%, the expert judgements were considered untrustworthy, as they too closely represented random judgement. Where this occurred, the AHP process was repeated. This study utilised an AHP software developed by Goepel (2012) to calculate indicator weights. The final output of the AHP (representing indicator and risk component weights to be utilised within the model is shown in (Figure 7).



Present Scenario (2020)

	HAZARD	AQ	IF	CF
1	Severity of River Flooding	34.40	19.00	23.40
2	Severity of Storm Surges	25.80	35.30	27.2
3	Temperature Rise	26.60	22.40	30.7
4	Drought Periods	6.10	14.50	4.70
5	Forest Loss	7.10	8.70	14.0

	EXPOSURE	AQ	IF	CF
1	Population Density	6.20	10.00	10.00
2	# Fishing Licences		48.90	48.90
3	Aquaculture Pond Area	55.80		
4	Agricultural Land Area	9.80	9.50	9.50
5	Economic Risk	28.20	31.50	31.50

	SENSITIVITY	AQ	IF	CF
1	Fisheries Production	50.50	67.70	67.70
2	Irrigation	8.50	14.30	14.30
3	# Aquaculture Ponds	23.80		
4	# Hatcheries	6.40		
5	Fisheries as Livelihood	10.80	18.00	18.00

	ADAPTIVE CAPACITY	AQ	IF	CF
1	Government Loans	6.90	6.90	6.90
2	Community Development	6.00	6.00	6.00
3	Value Chain Development	30.70	30.70	30.70
4	Education Level	2.40	2.40	2.40
5	Capacity Development	2.70	2.70	2.70
6	Mangrove Loss	7.60	7.60	7.60
7	Road Length	21.80	21.80	21.80
8	Ports/Landing Sites	21.80	21.80	21.80

Future Scenario (2040)

	HAZARD	AQ	IF	CF
1	Temperature Increase	49.40	42.70	51.40
2	Drought Periods	26.10	32.70	5.30
3	Sea Level Rise	3.20	4.90	12.20
4	Severity of River Flooding	14.00	12.00	5.30
5	Severity of Storm Surges	7.30	7.70	25.80

Figure 7: The relative weights of the risk components and the indicators used to reflect them for the aquaculture (AQ), inland fisheries (IF) and coastal fisheries (CF) sub-sectors.

Aggregating Weighted Indicators into Component- & Sub-Indices

The weights obtained from the AHP process were used to multiply the transformed data for each variable enabling indices to be calculated for hazard, exposure and vulnerability (whereby the vulnerability indices was comprised of sensitivity and adaptive capacity sub-indices). The risk component indices were then combined to derive an overall index of risk for each township.

For some variables, data was not available for all 87 townships. Where this occurred, the weight for that township was disproportionate to other variables. For example, data was not available for the number of ports and landing sites in Pauktaw township, Rakhine. The 21.8% weight given to this variable was disproportionate to the seven other variables within the adaptive capacity risk component (i.e. 21.8% / 7).

Assigning Risk Level Ranks to Model Outputs

Index scores were ranked for each risk component based on the following risk categories: very low (0-20%); low (20.1-40%); medium (40.1-60%); high (60.1-80%) and very high (80.1-100%). This enabled the relative level of each risk component to be easily interpreted and compared between townships. To improve the visualisation of spatial patterns generated by the risk assessment model, a series of maps were produced using ArcGIS 10.8.1 for the ranked index scores of each risk component.

Results

The following section provides an overview of key results from the different scenarios generated within the risk assessment model. The information presented intends to provide readers with a detailed understanding of both present and future risk for the fisheries sector within Myanmar at both a cross- sub-sector and intra sub-sector level of analysis at multiple administrative levels (i.e. state, district and township).

Cross Sub-Sector Analysis

Given variability in the type and number of indicators used to assess risk between the different fishery sub-sectors, a cross sub-sector analysis can only provide a basic understanding of potential differences in risk level within Myanmar's fisheries (based on Yangon, Ayeyarwady region and Rakhine state). The following results represent the average risk level for each sub-sector across the study area. This average value has been calculated from the risk level for each township within the study area (n=87) (Annex 3).

Results suggest that the aquaculture sub-sector is at lowest risk across the study area, in contrast to inland and coastal fisheries. Within the aquaculture sub-sector, a total of 39 townships were considered low risk, compared to 23 for inland fisheries and 37 for coastal fisheries. As such, inland fisheries were considered at greatest risk to impact from identified hazards amongst the fisheries sub-sectors, despite displaying an overall risk level of medium (Table 9).

Inland fisheries were considered highly vulnerable (n = 48). This was primarily driven by the sub-sectors' low adaptive capacity (n = 30) when compared to coastal fisheries (n = 24) and the aquaculture sub-sector (n = 24) (Table 9).

Future risk to coastal fisheries decreased, moving from 37 townships at medium risk within the present scenario, to 41 townships at low risk within the futures scenario. This is despite an overall increase in the impact of future hazard across the study area; moving from low (n = 23) to medium (n = 32) (Table 10).

Table 9: The **present (2020) risk level** of the aquaculture, inland and coastal fishery sub-sectors' ranging on a scale from very low to very high.

Risk (2020)	Risk	Hazard	Exposure	Vulnerability	Sensitivity	Adaptive Capacity
Aquaculture	Low	Low	Low	Medium	Very Low	Low
Inland	Medium	Low	Very Low	High	Very Low	Low
Coastal	Medium	Low	Very Low	Medium	Very Low	Low

Table 10: The **future (2040) risk level** of the aquaculture, inland and coastal fishery sectors ranging on a scale from very low to very high.

Risk (2040)	Risk	Hazard	Exposure	Vulnerability	Sensitivity	Adaptive Capacity
Aquaculture	Low	Medium	Low	Medium	Very Low	Low
Inland	Medium	Low	Very Low	High	Very Low	Low
Coastal	Low	Medium	Very Low	Medium	Very Low	Low

Intra Sub-Sector Analysis

Aquaculture Sub-Sector

Key Findings

- The **aquaculture sub-sector** has a **very low/low overall risk level** of being impacted by identified hazards within both present and future risk assessment models.
- Within **Yangon, overall risk** to the aquaculture sub-sector increased from **very low to low** by **2040** due to an increase in the future impact of hazards.
- The aquaculture sub-sector within **Maubin** township (Ayeyarwady state) and **Twantay** township (Yangon state) are considered at **very high risk** of being negatively impacted by identified hazards given both present (2020) and future (2040) risk levels.
- Rakhine townships (**Ramree, Gwa, Thandwe and Toungap**) ranked at **very high risk** being impacted by **future hazards** (2040) given predicted impact levels from climatic models.

Overview

The aquaculture sub-sector demonstrated a very low/low risk level across the study area. This was associated to the very low/low impact level of the identified hazards to aquaculture operations; and the low exposure and sensitivity of the system to these hazards. However, no differentiation between size of aquaculture installations was possible in the assessment and it is likely that very small-scale systems would have different vulnerability and risk compared with large scale operations. There was no production recorded in 35 townships across the study area (the majority of which were within Yangon state (n=34). As production levels contributed 50.5% of the weight to the sensitivity component of the model; the lack of aquaculture within these regions played a significant role in the overall risk score of low/very low for these townships. This was further driven by the lack of aquaculture ponds within these townships, which comprised an indicator within the exposure component, accounting for 55.8% of the overall components weight. Despite an overall sensitivity of very low, the total vulnerability of the sub-sector ranked medium given the systems very low adaptive capacity (Table 11).

The aquaculture sub-sector continued to demonstrate a very low/low risk level across the study area given future hazard impact levels. However, changes to the impact level of climatic hazards within the study area, led to several changes in the overall risk level of assessed states (Table 12).

- **Yangon was the only state where the aquaculture sub-sector demonstrated very low risk** to identified hazards. However, within Yangon an increase in the predicted impact of identified future hazards led the overall risk level to increase to low by 2040.
- **The overall risk of the aquaculture sub-sector in the Ayeyarwady decreased to very low/low by 2040;** however, the overall hazard level remained low.

Table 11: The **present (2020) risk level** of the aquaculture sub-sector within Yangon, Ayeyarwady and Rakhine states ranging on a scale from very low to very high.

Risk (2020)	Risk	Hazard	Exposure	Vulnerability	Sensitivity	Adaptive Capacity
Yangon	Very Low	Very Low	Very Low	Medium	Very Low	Very Low
Ayeyarwady	Low	Low	Low	Medium	Very Low	Very Low
Rakhine	Low	Low	Low	Medium	Very Low	Very Low

Table 12: The **future (2040) risk level** of the aquaculture sub-sector within Yangon, Ayeyarwady and Rakhine states ranging on a scale from very low to very high.

Risk (2040)	Risk	Hazard	Exposure	Vulnerability	Sensitivity	Adaptive Capacity
Yangon	Low	Very Low/Low	Very Low	Medium	Very Low	Very Low
Ayeyarwady	Very Low/Low	Low	Low	Medium	Very Low	Very Low
Rakhine	Low	Low	Low	Medium	Very Low	Very Low

Present Scenario

The aquaculture sub-sector was at very high overall risk within two townships across the study area. These townships were Maubin in the Ayeyarwady, and Twantay in Yangon (Figure 8a). However, the majority of townships across the study area exhibited low risk (n = 31) to the aquaculture sub-sector.

- ***Hazard***: Maubin was the only township to rank very high risk to hazards, this was followed by 11 townships positioned across the study area that ranked high risk (Figure 8b).
- ***Exposure:*** Four townships exhibited a very high exposure to identified hazards; these were, Maubin and Nyaungdon in Ayeyarwady, Twantay in Yangon and Pauktaw in Rakhine state (Figure 8c).
- ***Vulnerability:*** The aquaculture sub-sector within Maubin, Nyaungdon and Twantay all ranked highly vulnerable; this was primarily a consequence of their high sensitivity and low adaptive capacity (Figure 8d).
- ***Sensitivity:*** Maubin and Twantay were additionally the only townships to exhibit a very high sensitivity to identified hazards (Figure 8e).
- ***Adaptive Capacity:*** A total of 52 townships demonstrated very low adaptive capacity when considering the aquaculture sub-sector; Maubin and Twantay both exhibited low adaptive capacity. Notably, Labutta in the Ayeyarwady and Hlaingtharya in Yangon were the only townships within the study area to demonstrate a very high adaptive capacity (Figure 8f).

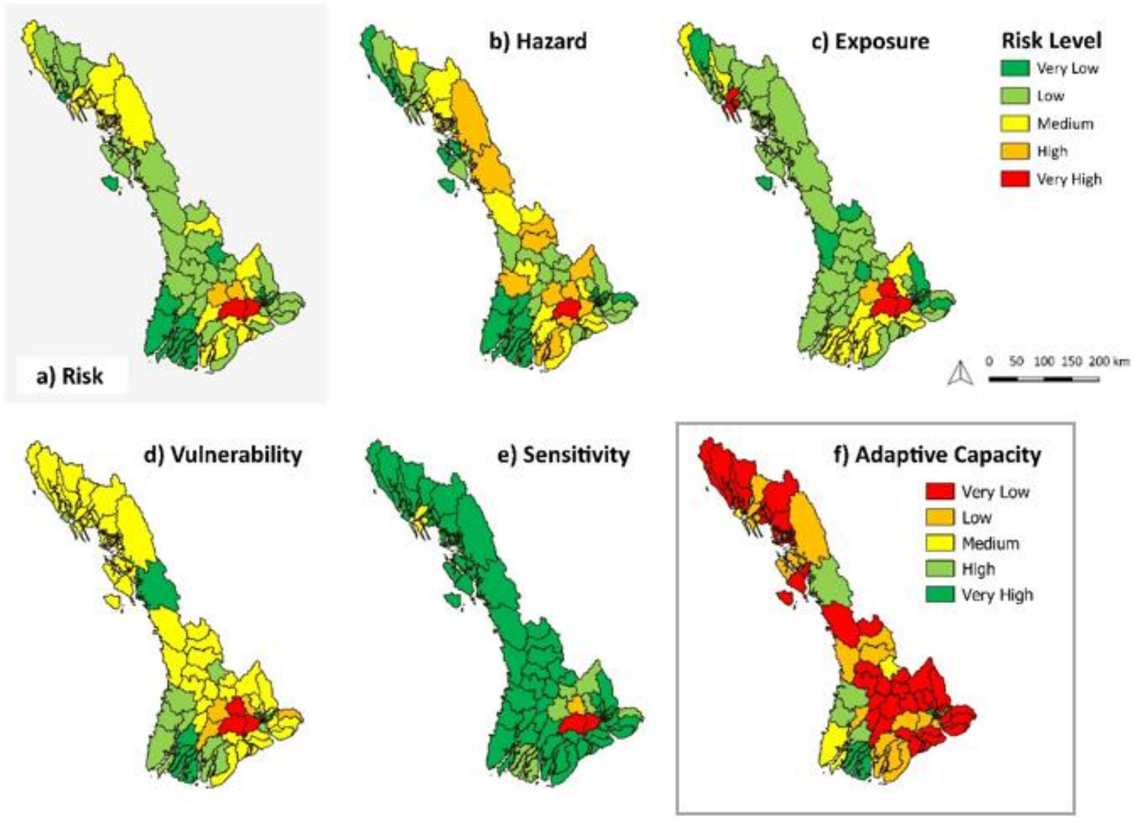


Figure 8: The overall a) risk level (and the risk level of assessment components: b) hazard; c) exposure; d) vulnerability; e) sensitivity; f) adaptive capacity) for the aquaculture sub-sector within townships across the study area (n=87).

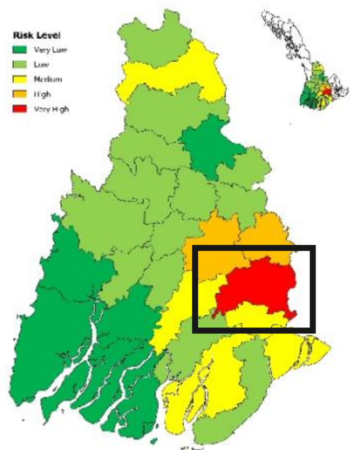


Figure 9: Overall risk of the aquaculture sub-sector across townships within Ayeyarwady. The location of Maubin (very high risk) is depicted by the black box.

Maubin had the highest relative score across three out of the four risk components [5](hazard, exposure and sensitivity) (Figure 9). The townships 'very high' risk score for hazard was largely determined by the indicators used to demonstrate river flooding and storms; with Maubin particularly prone to a high level of inundation following such events. This is due to the positioning of Maubin's urban centre on the west bank of the Ayeyarwady River. Estimations of flood extent from MUDRA show inundation (on average) to occur over a total area of 862.00m^2 for river floods and 900m^2 for storm surges. Additionally, the township had the relative highest score for exposure. Notably, the township exhibited a high economic risk level, in terms of infrastructural damage as a result of river floods and storms. This provides further evidence of the risk flood episodes pose to this township in terms of both the human population and urban and rural infrastructure. Maubin is one

[5] This specific case is an example where linkages to the FAO community based vulnerability assessments and the CRIMPS (Community Resource Integrated Management Plans) produced in each community can be made.

of four townships within Myanmar where the aquaculture sub-sector has developed most strongly. The very high exposure level within Maubin was primarily driven by the extent of the townships aquaculture pond area covering 45,827.70 acres. The large-scale extent of the aquaculture sector within Maubin additionally led this township to have the highest sensitivity level in the study area. This was driven by productivity levels, with 138,514.00 Viss produced in the 2018-19 'production year. The township additionally boasts the second greatest number of irrigation infrastructures (i.e. dams, weirs and sluices) throughout the study area (n=15). This acts to support the water supply to the aquaculture sub-sector; however, this additionally increased the townships overall sensitivity within the model. Notably, the township exhibited a medium risk score for adaptive capacity, which is relatively high in contrast to the 52 townships that scored very low. This acted to offset the townships overall risk level but failed to reduce overall risk from very high to high.

Future Scenario

The aquaculture sub-sector within three townships exhibited very high risk of impact. Maubin and Twantay continued to exhibit very high risk but were joined by Nyaungdon township in the Ayeyarwady ((Figure 10a).

Contrastingly, the four townships the exhibited the highest level of predicted hazards by 2040 were all situated in Rakhine and included Ramree, Gwa, Thandwe and Toungap (Figure 10b).

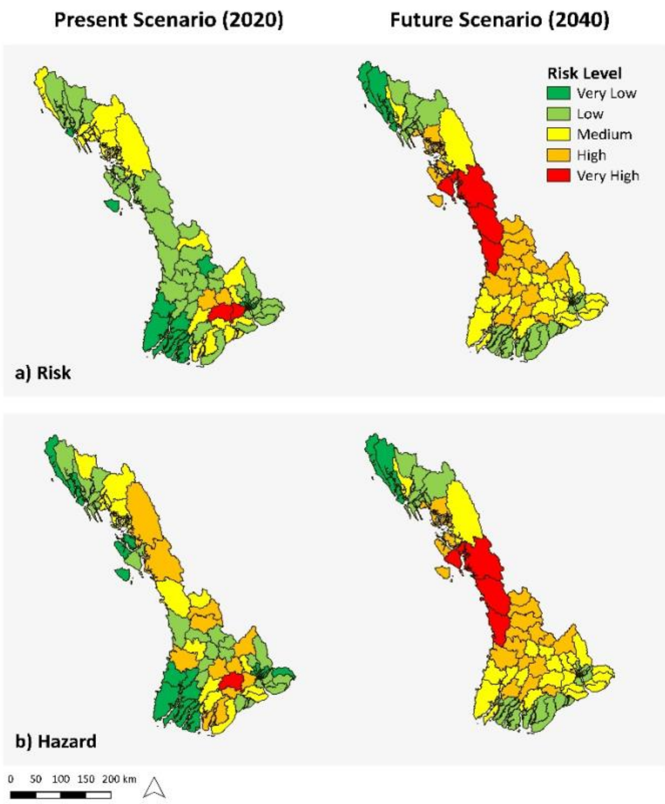


Figure 10: The overall a) risk level and b) hazard level for the for the aquaculture sub-sector within townships across the study area (n=87) given present (2020) and future (2040) risk assessment scenarios.

Inland Fisheries Sub-Sector

Key Findings

- **Risk** across the study area **ranged from low** (within Yangon) **to high** (within the Ayeyarwady), associated to hazard and exposure levels.
- **Across the study area**, the **inland fisheries** sub-sector exhibited **high vulnerability** to identified threats.
- At the township level, **Ayeyarwady** exhibited the **greatest number of townships** (n = 6) that were at **very high risk**, primarily exhibited by the states very low adaptive capacity and high sensitivity.
- **Hazard levels** were **greatest** within townships **in Rakhine state** for both the present (n = 3) and future scenarios (n = 5).

Overview

Risk level within inland fisheries varied between states/regions, with Yangon once again demonstrating the lowest overall risk level, and the Ayeyarwady the highest (Table 13).

- The high level of risk within the Ayeyarwady was driven by the region having a medium risk of being impacted by hazards across townships. Additionally, exposure within this state measured 'low' which was higher than that of Yangon and Rakhine which measured 'very low'.
- The low level of risk within Yangon was associated to the very low prevalence of hazards and the systems exposure to these hazards within the state.

Across the study area, vulnerability within inland fisheries measured high, this was associated to the very low adaptive capacity of all states to overcome risk within inland fisheries.

Within Rakhine, future risk within inland fisheries varied between townships leading the risk level across the state to range from very low to very high. Despite this observation, no change in the overall hazard level within the state was seen (Table 14).

Table 13: The **present (2020) risk level** of the inland fisheries sub-sector within Yangon, Ayeyarwady region and Rakhine state ranging on a scale from very low to very high.

Risk Component	**Risk**	**Hazard**	**Exposure**	**Vulnerability**	**Sensitivity**	**Adaptive Capacity**
Yangon	Low	Very Low	Very Low	High	Very Low	Very Low
Ayeyarwady	High	Medium	Low	High	Very Low	Very Low
Rakhine	Medium	Low	Very Low	High	Very Low	Very Low

Table 14: The **future (2040) risk level** of the inland fisheries sub-sector within Yangon, Ayeyarwady region and Rakhine state ranging on a scale from very low to very high.

Risk Component	Risk	Hazard	Exposure	Vulnerability	Sensitivity	Adaptive Capacity
Yangon	Low	Very Low	Very Low	High	Very Low	Very Low
Ayeyarwady	High	Medium	Low	High	Very Low	Very Low
Rakhine	Very Low/Low Very High	Low	Very Low	High	Very Low	Very Low

Present Scenario

A total of 7 townships exhibited very high risk when considering the inland fisheries sub-sector; however, 6 townships also ranked very low risk. Of the townships considered very high risk, six were positioned in the Ayeyarwady delta (Nyaungdon; Maubin; Wakema; Pantanaw; Labutta and Dedaye) and one within Yangon (Taikkyi) (Figure 11a). Within Ayeyarwady, one township (Myaungyma) was considered at very low risk.

- ***Hazard***: Across the study area, four townships were very highly impacted by identified hazards. These were primarily situated in Rakhine (Minbya, Ann and Toungap) with one positioned in Ayeyarwady (Hinthada) (Figure 11b).
- ***Exposure:*** Labutta (situated in the Ayeyarwady) was the only township where the inland fisheries sub-sector exhibited a very high exposure to identified hazards. This was closely followed by Nyaungdon, which exhibited a high exposure level (Figure 11c).
- ***Vulnerability:*** A total of eight townships were considered to have a very high vulnerability, these were all positioned within Ayeyarwady and included five of the townships where overall risk was also very high (Labutta acted as an exemption to this trend). This was driven by the very low/low adaptive capacity of these townships (Figure 11d).
- ***Sensitivity:*** Labutta was the only township that exhibited very high sensitivity, driving the townships' overall risk level of 'very high'. The majority of townships (n = 75) exhibited very low sensitivity when considering the inland fisheries sub-sector (Figure 11e).
- ***Adaptive Capacity:*** The majority of townships exhibited very low adaptive capacity (n = 45). Contrastingly, two townships exhibited very high adaptive capacity including Labutta (Ayeyarwady region) and Hlaingtharya (Yangon region) (Figure 11f).

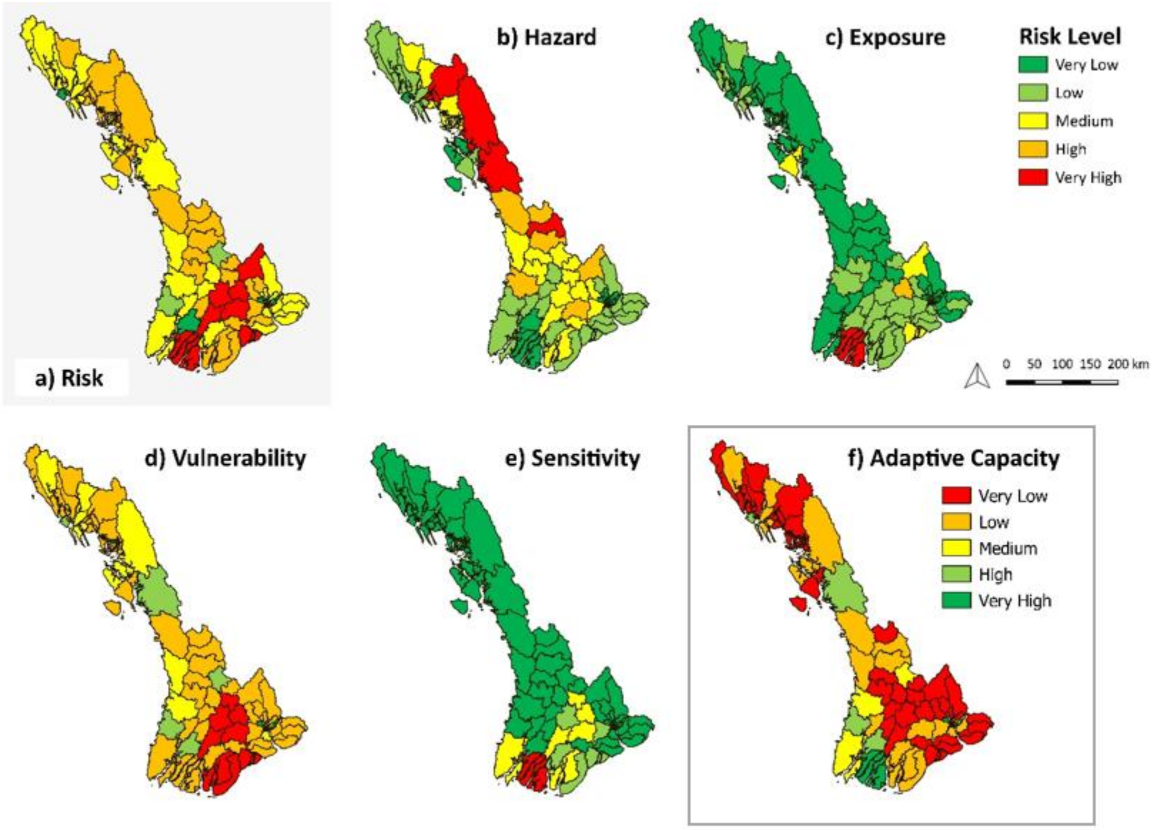


Figure 11: The overall a) risk level (and the risk level of assessment components: b) hazard; c) exposure; d) vulnerability; e) sensitivity; f) adaptive capacity) for the inland fisheries sub-sector within townships across the study area (n=87).

The inland fisheries sub-sector within Nyaungdon township was at the highest overall risk level (very high) across the study area. Its' overall risk level can be understood through its high score for exposure, medium scores for hazard and sensitivity and very low score for adaptive capacity. Most notably, Nyaungdon had the second highest overall exposure; this was driven by the extent of the townships agricultural land area (13,1262 acres) and its high economic risk score. The high exposure level for Nyaungdon was partially driven by the disproportionation of weights for the exposure component, as no data for fishing grounds existed within this township. The high value for production (25,241.00 Viss) (a component of sensitivity) suggests however that the exposure of fishing grounds within the township would be high; with Nyaungdon having the 7th highest inland fisheries production rate for 2018-19 throughout the study area. Nyaungdon had a very low adaptive capacity.

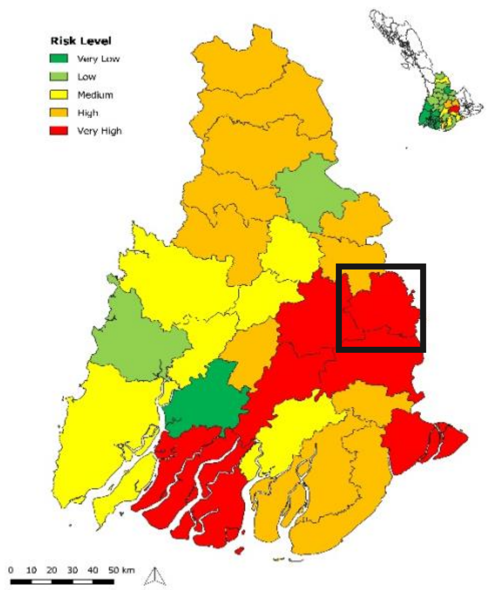


Figure 12: The overall risk of the inland fisheries sub-sector across townships within the Ayeyarwady Delta. The location of Nyaungdon (very high risk) is depicted by the black box.

This was the primary driver of its highest overall risk score across the study area, as Labutta scored highest for both the exposure and sensitivity components but had the highest adaptive capacity, reducing its overall risk level. Low levels of adaptive capacity within Nyaungdon were primarily driven by limited value chain development (i.e. wet markets, fish traders and wholesalers) (n = 4) within the township and low accessibility in terms of road infrastructure (98.10 miles) and the number of local ports and landing sites (n = 0) (Figure 12).

Future Scenario

Within the inland fisheries sub-sector, seven townships were considered very high risk given a futures outlook. This included the same six townships in the Ayeyarwady that were high risk in the present scenario, in addition to Ramree township in Rakhine (Figure 13a).

Given future predicted hazard levels, impact on inland fisheries was considered to be very high in six townships. These were primarily situated in Rakhine (Kyaukpyu, Ramree, Gwa, Thandwe and Toungap) with one (Myaungyma) positioned in the Ayeyarwady delta (Figure 13b).

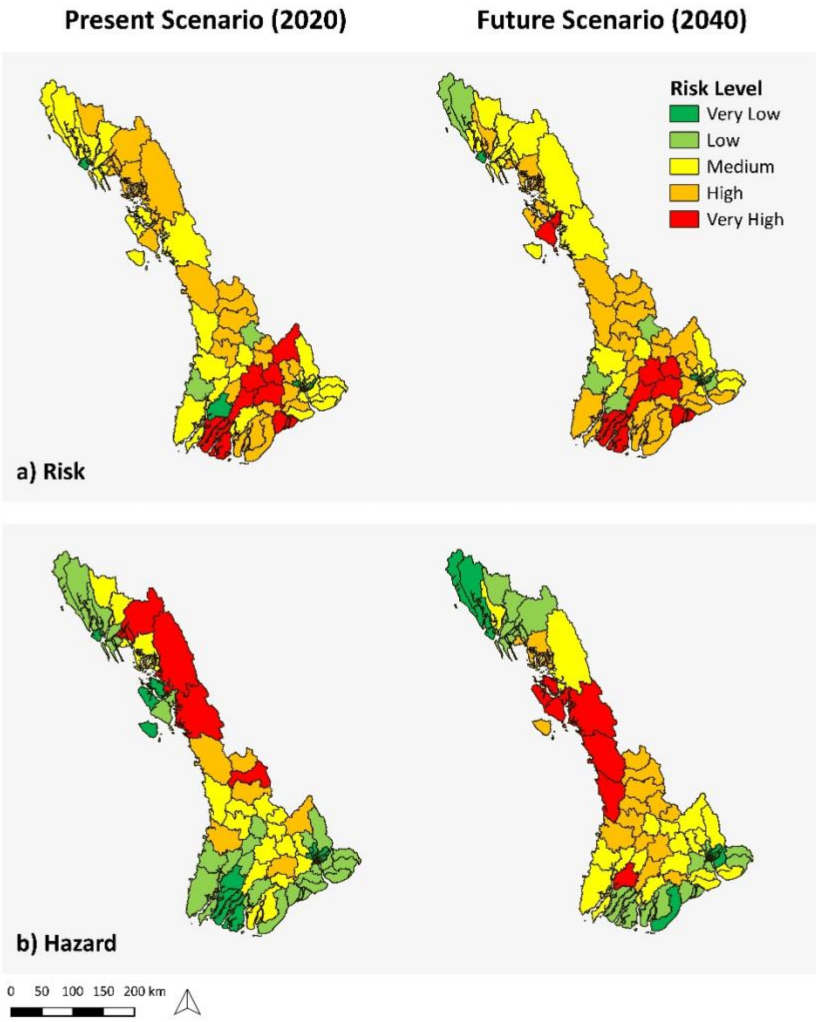


Figure 13: The overall a) risk level and b) hazard level for the for the inland fisheries sub-sector within townships across the study area (n=87) given present (2020) and future (2040) risk assessment scenarios.

Coastal Fisheries Sub-Sector

Key Findings

- **Risk varied between low and medium** across the study area, with Yangon exhibiting the lowest level of overall risk.
- The **sub-sector** exhibited a **very low adaptive capacity**.
- There was no difference in the overall risk to the sub-sector between the present and future scenarios.
- **Pyapon** township within the Ayeyarwady region was the only township to exhibit an overall level of **very high risk** given both the present and future scenario.

Overview

Risk to coastal fisheries varied between low and medium across the study area (Table 15).

- Coastal fisheries within Yangon were at lowest risk, compared to Rakhine and Ayeyarwady which were both considered at medium risk.
- The Ayeyarwady exhibited the highest hazard levels (ranking medium) and exposure levels (ranking very low to low).

Adaptive capacity ranked very low across the study area; this led the overall vulnerability of the sub-sector to rank as medium.

There was no difference in the overall risk level between the present and future scenarios across the study area (Table 16).

Table 15: The **present (2020) risk level** of the coastal fisheries sub-sector within Yangon, Ayeyarwady region and Rakhine state ranging on a scale from very low to very high.

Risk Component	**Risk**	**Hazard**	**Exposure**	**Vulnerability**	**Sensitivity**	**Adaptive Capacity**
Yangon	Low	Very Low	Very Low	Medium	Very Low	Very Low
Ayeyarwady	Medium	Medium	Very Low/Low	Medium	Very Low	Very Low
Rakhine	Medium	Low	Very Low	Medium	Very Low	Very Low

Table 16: The future (2040) risk level of the coastal fisheries sub-sector within Yangon, Ayeyarwady region and Rakhine state ranging on a scale from very low to very high.

Risk Component	**Risk**	**Hazard**	**Exposure**	**Vulnerability**	**Sensitivity**	**Adaptive Capacity**
Yangon	Low	Very Low	Very Low	Medium	Very Low	Very Low
Ayeyarwady	Medium	Medium	Very Low/Low	Medium	Very Low	Very Low
Rakhine	Medium	Low	Very Low	Medium	Very Low	Very L

Present Scenario

Across the study area, Pyapon in the Ayeyarwady region was the only township whose coastal fisheries exhibited very high risk. This was followed by ten townships across the study area that measured high risk. These townships were primarily positioned in Ayeyarwady (n = 7), with two in Yangon (Twantay and Taikkyi) and one in Rakhine (Minbya) (Figure 14a).

- ***Hazard***: Hazard levels were very high in two townships; these were both positioned within Rakhine (Ann and Toungap). The majority of townships (n = 39) exhibited very low impact levels when considering identified hazards. Pyapon ranked at high risk of impact from hazards (Figure 14b).
- ***Exposure:*** Labutta (situated within the Ayeyarwady region) was the only township that exhibited a very high exposure level. This was followed by Nyaungdon (also situated within the Ayeyarwady region), which was the only township to exhibit high exposure. The majority of townships across the study area exhibited very low exposure levels (n = 54) (Figure 14c).
- ***Vulnerability:*** Pyapon was the only township that was very highly vulnerable; this was primarily a factor of its very high sensitivity. The majority of townships exhibited a medium level of vulnerability when considering the coastal fisheries sub-sector (n = 61) (Figure 14d).
- ***Sensitivity:*** Pyapon was the only township that was exhibited very high sensitivity. This was followed by Labutta and Ngapudaw (situated within the Ayeyarwady region) which both exhibited high sensitivity (Figure 14e).
- ***Adaptive Capacity:*** The majority of townships exhibited low adaptive capacity to hazards which impact the coastal fisheries sub-sector (n = 50). Contrastingly, two townships (Labutta in Ayeyarwady and Hlaingtharya in Yangon) exhibited very high adaptive capacity (Figure 14f).

The very high risk of coastal fisheries within Pyapon township was primarily due to the extent of the fishing sector within this area. Coastal production levels (influencing the townships sensitivity score) were nearly double that to the second highest production township of Ngapudaw, with Pyapon producing 174,049.49 Viss over the 2018-19 production year. However, Pyapon scored relatively low in terms of fishing grounds, indicating potential data errors in the number of fishing licences that was used as a proxy variable for this indicator. This is further supported by the high-risk scores of Twantay and Danubyu within the sensitivity component, which, despite not being positioned along the coastline, scored highly in terms of fishing grounds.

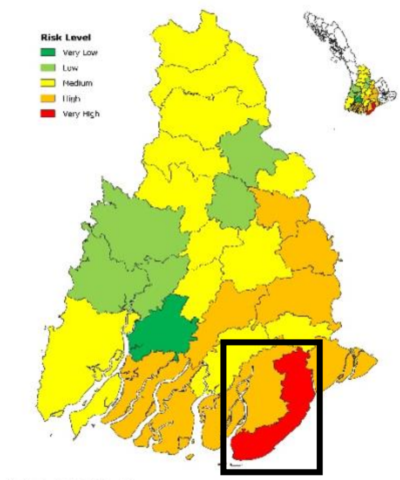


Figure 14: The overall risk of the coastal fisheries sub-sector across townships within the Ayeyarwady Delta. The location of Pyapon (very high risk) is depicted by the black box.

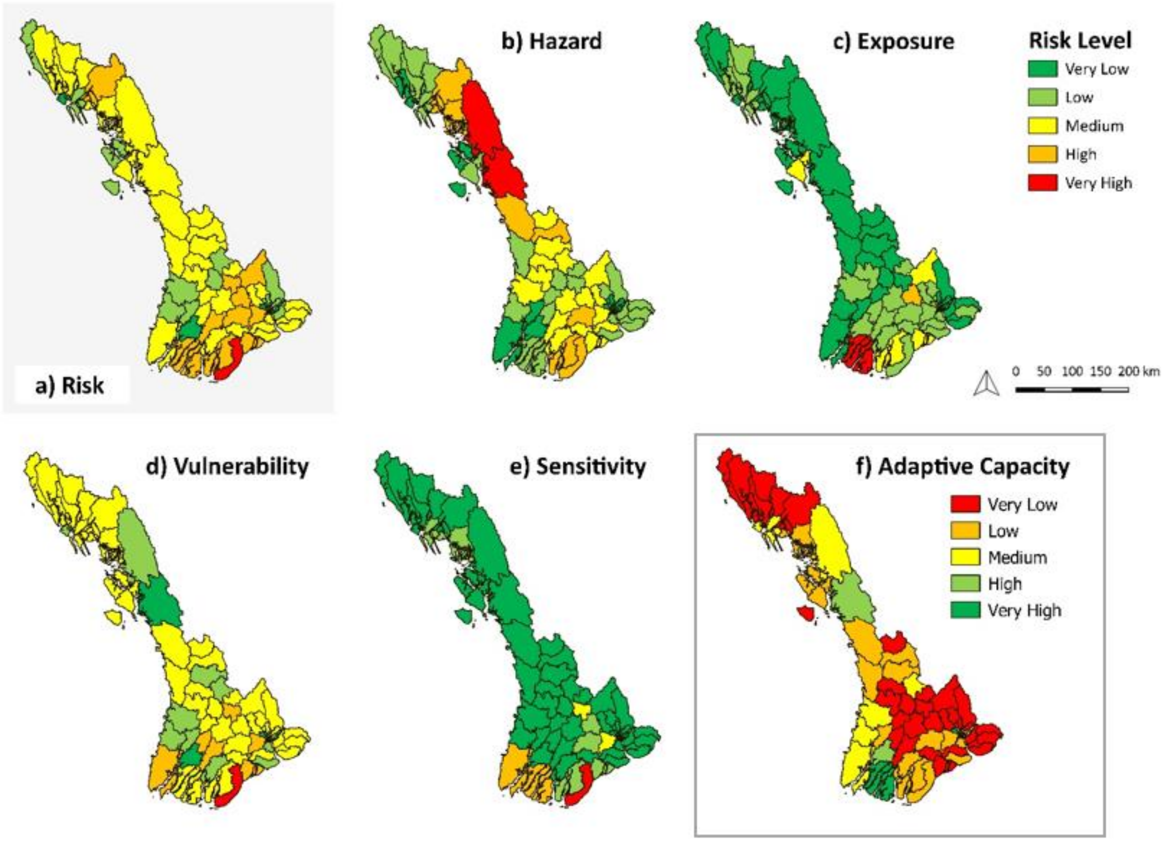


Figure 15: The overall a) risk level (and the risk level of assessment components: b) hazard; c) exposure; d) vulnerability; e) sensitivity; f) adaptive capacity) for the coastal fisheries sector within townships across the study area (n=87).

Future Scenario

Pyapon continued to be the only township which exhibits a very high-risk level when considering the futures scenario. The majority of townships (n = 41) within the study area exhibited a low level of risk when considering future hazard levels (Figure 16a).

Across the study area, seven townships were predicted to be very highly impacted by future hazard levels. These townships were primarily situated within Rakhine (n = 6); with one (Kyauktan) positioned within Yangon (Figure 16b).

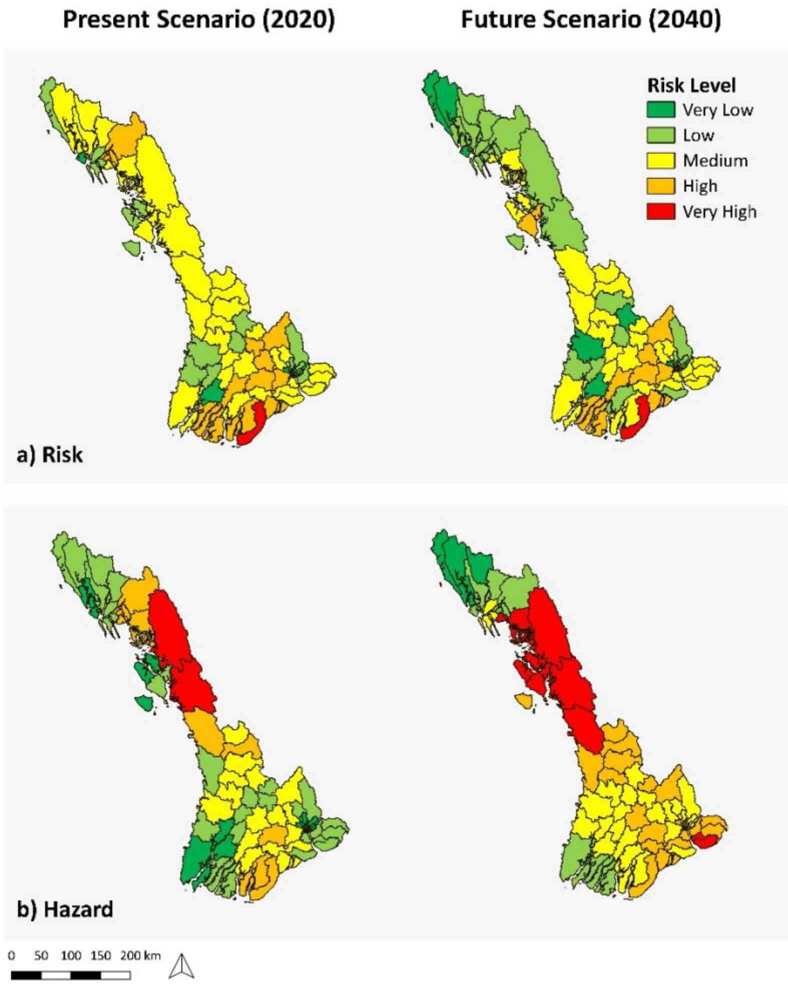


Figure 16: The overall a) risk level and b) hazard level for the for the coastal fisheries sub-sector within townships across the study area (n=87) given present (2020) and future (2040) risk assessment scenarios.

Discussion

The discussion is organised into three parts; 1) model limitations and mitigation responses; 2) interpretation of model outputs and 3) the identification of mechanisms to reduce risk. Recommendations forming part of the narrative are highlighted in bold text.

Part 1: Model Limitations & Mitigation Responses

Data Quality & Availability: Risk Components

Model outputs present a robust analysis of risk within the fisheries and aquaculture sector of southern Myanmar. However, the depth of analysis was significantly limited by the availability and quality of secondary datasets and due to Covid19 restrictions on field travel. **With this in mind, it is recommended that results from the risk assessment are utilised as an advisory tool and outputs combined with expert knowledge of the local context when results are used to inform policy recommendations.** This has been demonstrated in the previous section, where background knowledge has been used to complement risk assessment outputs, providing users with a greater understanding of the drivers' behind designated risk levels for a given sub-sector.

Limitations in data availability had a significant effect on the number and depth of indicators used within the model. This was notable in attempts to identify data that would represent indicators selected during consultation workshops; eventually leading to a number of indicators being excluded from the final model. Data availability varied significantly between risk assessment components. Where multiple datasets were available for a given indicator, usage was often then limited by poor data quality or a high percentage of missing data. This was specifically evidenced for indicators within the hazard risk component; where information on climatic variables were available from multiple sources but varied significantly in their accuracy. **Given the complexities in assigning reliable data to indicators, the data compilation and validity checking process within the present study was particularly rigorous.** The Ocean Health Index is another example of an index where dimensions are measured and scored for focal areas. Present STATUS is an area's current value compared to its reference point. TREND is the average percent change of a focal area status over the most recent five years. PRESSURES are the ecological and social factors that decrease status. RESILIENCE includes the ecological factors and social initiatives (policies, laws, etc.,) that increase status by reducing or eliminating pressures http://www.oceanhealthindex.org/.

Data Quality & Availability: Cross Sub-Sector Analysis

Data limitations also played a role in the depth of risk assessment analysis between fisheries sub-sectors. This meant that risk within each sub-sector was only differentiated by differences in production levels, where data was disaggregated by sub-sector. This limits the inference that can be given when comparing risk levels between the sub-sectors in terms of data inputs. However, differences in the weighting scores of indicators between sub-sectors acted to further differentiate risk levels between inland fisheries, coastal fisheries and aquaculture.

This highlights the importance of utilising expert knowledge to guide the AHP process within models that are limited by data availability.

The inability for the model to differentiate between sub-sectors via indicator use led to the emergence of a list of key variables that would be useful to numerous forms of analysis if collected by the relevant government department at a local or national scale. For example, within inland and coastal fisheries documentation of the types and number of gears used, alongside the number of fishing licences given to a specific sub-sector, would assist in developing a greater understanding of both the exposure and sensitivity of these systems. This is of particular note for gear types (or infrastructure including fishing vessels) that have the potential to be damaged as a result of a hazard. The additional documentation of detail within utilised variables may additionally allow future risk assessment analyses to further differentiate between the specific systems within a sub-sector. For example; a greater level of data availability that disaggregates fish and prawn aquaculture would allow for an analysis of any differences in risk level between the development of these different aquaculture products.

Interpretation of Risk between Townships and States/Regions

The lower and upper bounds of the data range for each variable was based on the data range across all townships within the study area. Therefore, the final risk level of each township can be directly compared to any other township across the study area. As a result, when comparing risk levels between townships within a given state/region, the full data range may not be represented (as the upper and/or lower bound of the data may not occur within one of these townships). Consequentially, direct comparison of the risk level between townships in a state can still occur; but it must be considered that if no townships score 'very high' this is because these townships are being compared to all within the study area. Where an analysis of risk is desired specifically for a given state, or district, the model would be required to be re-run with the bounds of the data range set within the desired area. The model should be considered as flexible enough to be used for different framings e.g., leasable fisheries or large scale aquaculture and at different scales from community to national. Thus the purpose of the assessment will drive the construction of the model.

Consideration of Natural Disaster Events

The present risk assessment is undertaken specifically for climate change and considers natural hazards in regard to non-extreme events, for example annual flooding patterns and drought levels. This means that extreme hazardous events (i.e. large-scale natural disasters that cause great damage or loss of life) such as cyclones, tsunamis and extreme flood events were excluded from the analysis. This primarily occurred due to the limited availability of data at the township level documenting the impact of natural disasters. Such data is available at a wider administrative level. For example, the variable used to represent flooding provided an estimate of the total flooded area in 2020 based on the average impact of historical flood events (MUDRA 2020). This provides a basic understanding of the impact level from flooding within a given township; however, fails to represent the existence of more extreme seasonal flood events, which affected over 230,000 people in 2019 and caused 75 deaths (MIMU 2019). As monsoon flooding is a particular concern within the Ayeyarwady region, the ability to include this hazard within the model would be an advantage to overall risk assessment outcomes (SEI 2018). As such, the development of datasets that provide detailed information on the impact of natural disasters at the township level would enable the risk assessment model to provide a more robust analysis of the overall risk hazards impose on a sub-sector. This may be particularly important if the number and intensity of natural disaster events increases as a consequence of climate change (CFE-DM 2020).

Given the inability for the model to consider the impact of natural disasters within a given township, it is important to complement model outputs with expert knowledge, enabling areas to be highlighted that may still be experiencing long-term impacts from a natural disaster event. Within the study area, Cyclone Nargis in 2008 represents a key example; disproportionately impacting upon the fisheries and aquaculture sector in specific townships across the study area, and continuing to affect their extent and production levels to this day (CFE-DM 2020). Despite failing to consider the direct consequence of Cyclone Nargis, the model includes indicators that represent the present context of the fisheries and aquaculture sector (e.g. production levels and pond area etc.,). This acts to offset the direct exclusion of a given disaster event from the model, as these indicators will indirectly reflect the long-term persistence of any direct impacts from the disaster as it stands in the present day.

Assessing Sectoral Risk Levels in Low/Non reported Fisheries and Aquaculture Areas

Throughout the study area a number of townships existed where fisheries and aquaculture played a limited role or was not reported at all. This was evidenced in the variables used to represent indicators including fishing grounds and production levels, where data showed the absence of fishing licences, aquaculture ponds and production volumes. Despite the absence of reported fisheries/aquaculture sectors within these townships, they were still included within the risk assessment model. As a result, these townships generated an overall risk score of very low/low, as the indicators used to represent the extent of the sector comprised a significant component of the weight used to calculate different risk components. The decision to include these townships within the model was twofold. Firstly, in many regions small-scale subsistence level fishing is known to occur. This is often not included within official DoF statistics. The inclusion of 'fisheries absent' townships within the model can therefore reflect the overall risk score for a given sector when considering the other indicators that comprise risk. This can provide local managers with an idea of the key factors that may be influencing any small-scale subsistence fishing. This is important given the role subsistence fishing plays in supporting the diets and nutrition of local communities; which is of particular note in remote rural regions (Dubois *et al.* 2019). Secondly, the decision to include these townships allows models outputs to be useful from a planning perspective; with managers capable of considering potential risk levels (and developing mitigation strategies to reduce risk) in an area where sectoral development is being considered. Where model outputs are utilised in this manner, analysis of results from the futures risk assessment scenario will be particularly beneficial. This will enable planners to incorporate near-future climatic variability into possible development plans.

Part 2: Interpreting Model Outputs

Interpreting Sub-Sector Model Outputs

This part of the discussion is organised into two main sections; 1) by sub-sector, 2) by state/region. Recommendations forming part of the narrative are highlighted in bold text. It should be noted that when interpreting the outputs of the model, a lot of heterogeneity that are extremely important characteristics of both the social (e.g. wealth status, ethnicity, gender, etc.,) and fishery systems (priority economic fish species, types of fish etc.,) cannot be differentiated. This is a product of the scale and scope of the assessment. However, the model is flexible enough that it can be adapted and re-run for specific purposes such as with a food and nutrition or poverty focus.

Aquaculture Sub-Sector

The aquaculture sub-sector has a low overall risk level; with only two townships (Twantay in Yangon and Maubin in Ayeyarwady) across the study area exhibiting a very high risk level. These townships form part of the main aquaculture production hub, representing 90% of total production in the country (Belton 2015). The area is dominated by large-scale operations; however, satellite imagery suggests numerous small-scale ponds can also be found in the area (Belton 2015). This highlights the need for a **multi-level approach to risk assessments, enabling vulnerability indicators to assess the overall risk level for each segment within a sub-sector.** For example, within Rakhine the aquaculture sub-sector is primarily comprised of coastal shrimp trap and hold systems (as well as some more intensive prawn farming practices). In order to reduce the sub-sectors vulnerability, it will be important **to develop plans that are more specific to the dominant component of the sub-sector;** for example, the development of adaptation plans that centre around mangrove friendly aquaculture, highlighting the double role of mangroves as both a production zone and as a natural barrier against hazards.

The overall risk of the aquaculture sector increased when considering the estimated extent of future climatic hazards. This was primarily associated to temperature increase and the increased length of drought periods. The inclusion of the forward thinking futures scenario within the model has enabled this to be identified as a key future hazard for the sub-sector. As such, **managers can select adaptation strategies that will be beneficial considering future environmental conditions.** For example, the **development of climate-smart aquaculture practices** that take into account higher water temperatures and lower water supply. This may be done via the selection of species that are more tolerant to large temperature variations and lower dissolved oxygen levels.

Inland Fisheries Sub-Sector

The inland fisheries sub-sector had the greatest number of townships that scored very high risk within the model. This was primarily due to elevated exposure levels (particularly in the Ayeyarwady region) due to the high number of fishing licences. **As the extent of the system**

is not something that can be mitigated against, the implementation of measures that prevent damage may be beneficial. For example, implementing Early Warning System (EWS) can help reduce the potential impact of a given hazard, by giving those within the management of the sub-system time to protect fisheries related infrastructure such as vessels and gears. A significant component of the inland fisheries sub-sector within the Ayeyarwady occurs on a small-scale. It is this component of the sector that exhibits an exceptionally low level of adaptive capacity. **Given the large number of households within the region that depend upon fishing as their primary livelihood, enhancing local-scale adaptive capacity is imperative.** This can be done via the implementation of a few relatively easy interventions (i.e. developing better market infrastructure and accessibility) in a manner that would help structure the sub-sector in a more organised way.

Coastal Fisheries Sub-Sector

The futures model suggests coastal fisheries will be significantly impacted by storms by 2040. The identification of storms as a key and increasing hazard in coming decades once again highlights the utility of the predictive nature of the future model when considering potential adaptive measures within a sub-sector. For example, the implementation of innovative technologies (such as boat radios and meteorological equipment), would provision fishers with a localised form of EMS. This has the potential to prevent both loss of life and fisheries infrastructure.

Interpreting State/Region Model Outputs

Yangon

Overall results from the risk assessment model reveal all three sub-sectors to exhibit a medium score for contextual vulnerability within Yangon region. This is primarily the result of the regions' very low sensitivity score, counteracting a low outcome for adaptive capacity. The low sensitivity of the region was anticipated given the significant number of townships that are heavily urbanised and do not contribute to the fisheries and aquaculture sector. 33 or the 44 townships within Yangon region were located within the urbanised area managed by the Yangon City Development Committee (YCDC). Within these townships, fisheries production only occurred in locations where fish were landed on the banks of the rivers in Yangon (Pun Hlaing; Hlaing; Yangon and Bago), and comprised landings for both the inland and coastal fisheries sub-sectors. Given the urbanisation of Yangon region, the areas low adaptive capacity was an unanticipated result. This was predominantly driven by the limited existence of fish markets, traders and wholesalers within the area that comprised the value chain development indicator. **As such, the development of additional infrastructure to support fish processing and trading within the region would reduce the overall vulnerability of the fisheries and aquaculture sector**. However, as townships under the YCDC management area provide no and/or a limited contribution to fisheries and aquaculture; **adaptation plans may be better focused in areas where the sub-sectors provide an important contribution to employment, income and local nutrition.**

Ayeyarwady

The model demonstrates the elevated risk that river floods and temperature rise pose to the fisheries and aquaculture sector within the Ayeyarwady region compared to the rest of the study area. This is particularly pertinent for the aquaculture sub-sector, given the potential for flood induced damage to aquaculture installations. **A number of practical solutions exist for fish farmers to reduce the impact of flood events, these include: i) raising the height/depth of ponds; ii) placing netting around the pond to prevent fish escaping/becoming washed out during flood events.** These solutions reflect the benefit of adopting the IPCC (2014) risk assessment framework, which addresses contextual vulnerability in anticipation of a hazard. Where such solutions to potential hazard impacts are identified and applied, the overall vulnerability of the sub-sector can be reduced, limiting the potential impact of future hazard events.

Ayeyarwady is the most important region for inland fisheries production (and employment) across Myanmar. The high level of vulnerability of the inland fisheries sub-sector in the Ayeyarwady region is reflected by these high production levels, increasing the sensitivity of the sub-sector throughout the area. Given the region's proximity to Yangon (where demand for fish products is increasing due to an increasing population, particularly of urban middle class households) **further increases in inland fisheries productivity can be expected in the coming decades. This will act to further increase the sensitivity of the sub-sector, and thus its vulnerability level. This highlights the importance of focusing on the adaptive capacity of the system and implementing preventative measures to reduce potential hazard impacts prior to (or in tandem with) sub-sector development.**

Rakhine

The fisheries and aquaculture sub-sectors within Rakhine state were most likely to be impacted from temperature rise given both the present and future modelling scenarios. As the area is one of the three main coastal fishing zones within Myanmar's waters, this may bear particular significance to the coastal fisheries sub-sector (FAO 2019). It is not possible to directly infer the consequences of increasing temperatures to coastal fisheries; however, evidence suggests that impacts may be significant (Allison *et al.* 2009; Barange *et al.* 2014). For example, an increase in sea surface temperature can lead to more frequent harmful algal blooms, thereby impacting fish productivity (Townhill *et al.* 2018). Where such impacts occur, the development of mitigative adaptation measures on a small scale (i.e. state level) are not possible; with direct measures to reduce climate change effects requiring broadscale international input. As such, in areas where future climatic conditions may negatively impact on the productivity of a sub-sector (thus influencing employment, incomes and nutrition); **focus should lie in the implementation of capacity building techniques that can support the transition of local communities into alternative livelihoods.** This is reflected within the indicators used to assess adaptive capacity, which included evidence for capacity building such as DoA training and education level. For example, Rakhine had the lowest average literacy rate (used to reflect education level) across the study area. Studies have shown that higher educated households are more capable of pursing multiple livelihood options and are better at adapting or coping with the effects of climate change**. Therefore, the development**

of training schemes that focus on capacity development within other key sectors across the state (including agriculture and prawn aquaculture), may act as a key mitigative option. This could reduce the potential impact of climate change on the human population (i.e. income loss); whilst **redirecting the output of the coastal fisheries sub-sector to other areas (i.e. prawn aquaculture), thus supporting the continued nutrition of local communities.**

Part 3: Mechanisms to Reduce Risk

This section aims to highlight a small number of approaches and strategic responses needed to reduce risk. It is based exclusively upon outputs of the model (as opposed to generic knowledge on CC adaptation from the literature) and is thus specific to and dependent upon the availability of data used in the assessment. Selected recommendations are highlighted in bold within the text and a number of additional recommendations at the end of the section.

Reducing Contextual Vulnerability

By identifying indicators that drive vulnerability, adaptation strategies can be developed that act to reduce a systems' vulnerability (and thus the overall risk level) by a) reducing sensitivity; or b) increasing adaptive capacity. In terms of data availability sensitivity was the least well represented component in the risk assessment. The resulting indicators used to reflect the sensitivity of the fisheries and aquaculture sector focus on the extent of the fisheries system (e.g. spatial coverage, production rate, direct employment and associated infrastructure) without suitable indicators to adequately encapsulate fully its social dimensions. As such, adaptation strategies derived from the model must focus on the development of the fisheries systems' adaptive capacity. Adaptive capacity indicators centred around the infrastructure that supports the system and the socio-economic status of those directly involved in daily activities. **As a result, within the risk assessment framework it is the adaptive capacity component that managers should focus on.** Notable outputs from the model highlight the consistent impact of (1) low market access; (2) accessibility and (3) opportunities for sustainable livelihoods, on adaptive capacity.

Increasing Adaptive Capacity

Given the low overall adaptive capacity across all three states/regions, increasing adaptive capacity services (represented by indicators under this component) could arguably be the most effective way that the GoM can reduce the risk to the fisheries sector. Given the outputs noted above investments which target increasing; 1) access to or number of markets, 2) accessibility to roads and ports, and 3) alternative livelihood options should be prioritised.

1) **By increasing access to, or the number of markets, the adaptive capacity of the sub-sector (/people) increases as a result of increasing possibilities both for sellers (increased number of buyers of fresh fish or fish products so producers are less dependent on middlemen), and buyers** (a larger supply and variety of goods and services

is available, which may drive prices down). Easier access to or wider availability of fresh fish and fish products has the potential to have a positive impact on food and nutritional security in the region.

2) By improving connectivity through increasing accessibility to roads and ports, reflecting the fact that better connectivity would allow easier access to a wide range of services thereby increasing the capacity to adapt.

3) **Providing people in the fisheries sector with increased/alternative livelihood options should also be a priority area of focus as part of a strategy to reduce risk to the fisheries sector. This might include climate smart options such as integrated fish agriculture farming systems such as rice-shrimp o rice-fish and vegetables to increase resilience, optimise land and water use and reduce chemical use for food nutrition and income improvements utilising the same unit land area.** By increasing education levels and literacy rate, or by organising specific vocational trainings, fishing or fish farming households can reduce their dependency, in terms of income and food, on fishing or fish farming through the adoption of alternative livelihood options. If households become less dependent on fish as a source of income or food, this could potentially contribute to an increase of the biological/ecological situation, particularly for capture fisheries. If fishing households can rely on alternative sources of income, the fishing pressure could be reduced, and more sustainable fishing methods or stock management can be implemented.

4) Cross cutting the above options, access to finance (represented in our model by the number of banks and microfinance schemes per township) is frequently mentioned as a limiting factor in the development of the (small-scale) fisheries sector. Better access to credits and loans can contribute to an improvement in the quality of fish products produced by the aquaculture sub-sector**. If small-scale farmers have access to loans, they can invest into quality inputs, decent infrastructure and capital goods, which can lead to a professionalisation of the smallholder segment of the sector.** Producing higher-quality products might grant small-scale producers access to more lucrative, export markets. Higher revenues from fish and fish products for fish farmers can then in turn be reinvested into the sector, furthering its overall development.

A focus on the development of a systems' adaptive capacity is further reflected by the increase in the relative risk level of a sub-sector within a township, as the extent of the fisheries and aquaculture sub-sector continues to develop over time. Based on the indicators used within the present model, where the size of a sub-sector increases, so does the sub-sectors overall sensitivity, and thus vulnerability. **As such, managers should be forward thinking in their approach to adaptive capacity measures; ensuring implemented strategies not only meet but exceed present day demand for vulnerability reduction.** This is particularly important within the Government of Myanmar's commitment to the Sustainable Development Goals, particularly goal 13: 'climate action "take urgent action to combat climate change and its impacts"', but can also be linked to goals 1: no poverty and 2: zero hunger due to the fisheries sector's contribution to food and nutrition security, and household income.

This forward-thinking approach further extends to the consideration of future hazards, and how the mitigation of adaptive capacity may reduce their predicted impact. For example; protecting key infrastructures (e.g. fish markets and landing sites) from an increased number (and intensity) of storm and flood events will increase the adaptive capacity of the system by reducing the potential for impact by future hazards. This reflects the manner in which adaptation measures can be indirectly associated to adaptive capacity indicators.

Guiding Integrated Inter-Sector Planning and Policy

Integrated planning is vitally important to guide strategic investments to increase resilience and reduce risk of the fisheries sector. Whilst fisheries' significant contribution to food security and economic wealth is recognized in national policy statements regarding the development of the fisheries sector, fisheries often still remain undervalued and overlooked with the fisheries sector receiving only a small proportion of the agriculture development budget (e.g., less than 1% is assigned to fisheries compared with approximately 50% for irrigation, thereby undermining the potential to reduce risk and potentially increasing its vulnerability as a result of barriers to fish migration as a consequence of increased irrigation infrastructure.

Through the integration of the risk assessment model with other suitable data sets there is an opportunity to develop a decision support tool for planners and managers that can also be used with communities. This decision support system could incorporate a database utilising data from experimental trials e.g., the adaptation community based plans and linked pilots being conducted by the FAO FishAdapt project in 120 communities in the same areas as the ones covered by this analysis as well as a number of different integrated agriculture aquaculture production systems. The models and maps generated from the system will be used in integrated participatory planning processes that FishAdapt is following on their targeted communities and at different scales to ensure the needs and aspirations of end users are included and deliberated over in order to tailor and target investments most suited to reducing risk in the fisheries sector.

Recent global attention to the importance of integrated climate resilient food production systems now present an opportunity as food, stated in the recent Eat Lancet Commission study, is the single strongest lever to optimize both human health and environmental sustainability on Earth. Risk assessments can engage with this global challenge by helping to tailor and target investments where they are needed most, to sustain and enhance the fisheries sector and the people operating within it.

The risk assessment model and its outputs can be used in planning and policy dialogues with potential to influence fisheries sector and related policies.

Further Recommendations [6]

- Develop participatory adaptation plans and business models based on risk assessment priorities to guide investments in the sector, following the FishAdapt model
- Consider adapting the model for different thematic foci, e.g., nutrition, food security, individual fish stocks of economic importance, infrastructure, markets, institutions, governance arrangements etc.,
- Develop and implement a national methodology for collecting datasets that would aid in the depth/quality of future risk assessment analyses.
- Linked to the recommendation above on national data collection, develop local GoM capacity to conduct a self-assessment of risk in the fisheries sector at regular intervals.
- Consider incorporating the risk assessment model as one of a number of different data layers towards the development of a comprehensive decision support and management tool. This could include suitability mapping and scenarios for pilot adaptations (e.g. FishAdapt community adaptation pilots) and other associated geospatial tools.

Concluding remarks

This technical report outlines the findings of an indicator-based climate risk assessment for fisheries and aquaculture-based adaptation in Myanmar. It is the product of a collaboration between FAO FishAdapt team and WorldFish Myanmar and consultations with government partners at Union,State and Region, district and township levels. The risk assessment following the IPCC AR5 2014 methodology was conducted over a nine-month period in three states and regions (Rakhine, Yangon and Ayeyarwady) for the fisheries sector (inland freshwater, coastal and aquaculture sub – sectors). The scale of intervention was across all 87 townships across the three states and regions considered most suitable to address the FishAdapt objectives and the needs and opportunities for climate adaptation response in Myanmar. The outbreak of the Coronavirus pandemic and the ensuing restrictions on travel and assembly required a somewhat modified approach to that stated in the LoA where local and expert knowledge was used in place of larger sector consultations - for example in assigning the weighting used in the AHP process. Never the less the project deliverables were completed as agreed and on schedule.

[6] A number of these recommendations have potential to be explored in a follow on letter of agreement between WorldFish and the FAO

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Annexes

Annex 1: Criteria used for Climate Impact Assessment Literature Review

The climate impact assessment literature review used a list of selected criteria, which was compiled with inputs from various experts on Myanmar and on the fisheries sector. There were 43 criteria, grouped under 8 categories.

1. Geographical location (where is it taking place?)
2. Research questions and objectives
3. Ecosystem targeted
4. Sectors addressed (what is it looking at, which risks are considered?)
5. Themes addressed (what are the themes addressed in the methodology, are the focuses related to this risk assessment?)
6. Scale of the risk assessment (what geographical scale is considered?)
7. Scope of the risk assessment (how broad is the assessment?)
8. Credibility of the methodology (how rigorous?)

Additionally, pros and cons of each method were listed to highlight the overall approach, what framework was used and features that make them unique.

Annex 2: Analysis of Climatic Variables Used to Represent Hazard Indicators

1. **Temperature Increase**

Source: (WorldClim)

Present Scenario (2020) Analysis: https://www.worldclim.org/data/index.html

Monthly maximum and minimum temperature values (°C) were downloaded from the WorldClim database for a ten year period (2010-18). These were obtained as downscaled GeoTIFF files with a spatial resolution of 21 km^2. GeoTIFF files were imported into ArcGIS enabling minimum/maximum temperature per annum to be calculated within the bounds of each township using zonal statistics. Annual statistics were then utilised to calculate a proxy for 'temperature increase' by finding the difference in temperature range (i.e. subtracting the maximum from the minimum temperature per annum) over the 10 year period.

Future Scenario (2040) Analysis: https://www.worldclim.org/data/cmip6/cmip6climate.html

Future projected monthly maximum temperature values (°C) were downloaded from the WorldClim database for a twenty year period (2020-2040). Modelled temperature values were based on a 'middle of the road' socioeconomic pathway; with an anticipated average temperature increase of 2.4°C by 2081-2100 relative to an 1850-1900 baseline. To overcome variation in modelled temperature projections, monthly maximum averages were taken from three general circulation models (GCM) (BCC-CSM2-MR; CNRM-CM6-1; MIROC6). These GCM's were selected due to their widespread use in analyses of future climatic conditions within scientific reports that encompass the study area. Data was obtained as GeoTIFF files with a spatial resolution of 21 km^2. GeoTIFF files were imported into ArcGIS and zonal statistics calculated for annual maximum temperature values within the bounds of each township. To calculate the projected temperature increase within each township, the maximum temperature for 2040 was subtracted from the maximum value for 2020.

2. **Sea Level Rise**

Source: (CRESIS) https://cresis.ku.edu/content/overview-and-credits-sea-level-rise-maps

Sea level rise inundation zones were calculated from the Centre for Remote Sensing of Ice Sheets (CReSIS) Global Land 1km Base Elevation digital elevation model. This dataset provides inundation data at a 1km spatial resolution for sea level rise at 1-6m. Given IPCC predictions of sea level rise reaching approximately 0.22-044m by 2090, the 1m sea level rise scenario was selected for analysis. Potentially inundated areas were computed based on elevation and proximity to the current ocean shoreline. Data was imported into ArcMap and zonal statistics used to calculate the total area that would be inundated by a 1m level in sea rise within a given township.

3. **Drought (WASP)**

Present Scenario (2020) Analysis

Source: (WASP)
https://iridl.ldeo.columbia.edu/maproom/Global/Precipitation/WASP_Indices.html

To calculate drought, the Weighted Anomaly Standardised Precipitation (WASP) index was utilised. This index gives an estimate of the relative deficit or surplus of precipitation within a given month, by calculating anomalies in precipitation rate. Anomalies are based on monthly rates of precipitation and how much these depart from the long term monthly precipitation average (1980-2010). The WASP index then provides an estimate of drought per month based on a precipitation scale of dry (-3 – 0) and wet (0 – 3) conditions. This study utilised monthly WASP index values to calculate the average number of months subjected to drought conditions in a given year. To do so, index values were converted to (1) drought or (0) non-drought conditions, where any value below zero was considered ‘drought’. To calculate an average annual estimation of drought between 1999-2019, the number of months a township was subjected to drought per annum was calculated.

Future Scenario (2040) Analysis

Source: (SPEI) https://data.jrc.ec.europa.eu/dataset/jrc-climate-spei-drought-helix-ec-earth-1975-2100

The Standardised Precipitation Evapotranspiration Model (SPEI) was utilised for the assessment of future drought as (unlike the WASP index) this provided future estimates of global conditions. Modelled data derived from GDFL-ESM2M model was selected for analysis, as this covered the appropriate future time-scale for the study. SPEI data was presented in like to the WASP index (calculating monthly drought conditions on a scale from dry (-3 – 0) to wet (0 – 3)); and was therefore analysed in a concurrent manner. Results from the analysis show the total number of months a township is expected to be subjected to drought conditions between 12/2020 to 12/2040.

Annex 3: Radar Diagrams: Cross-Sectoral Risk Assessment Results

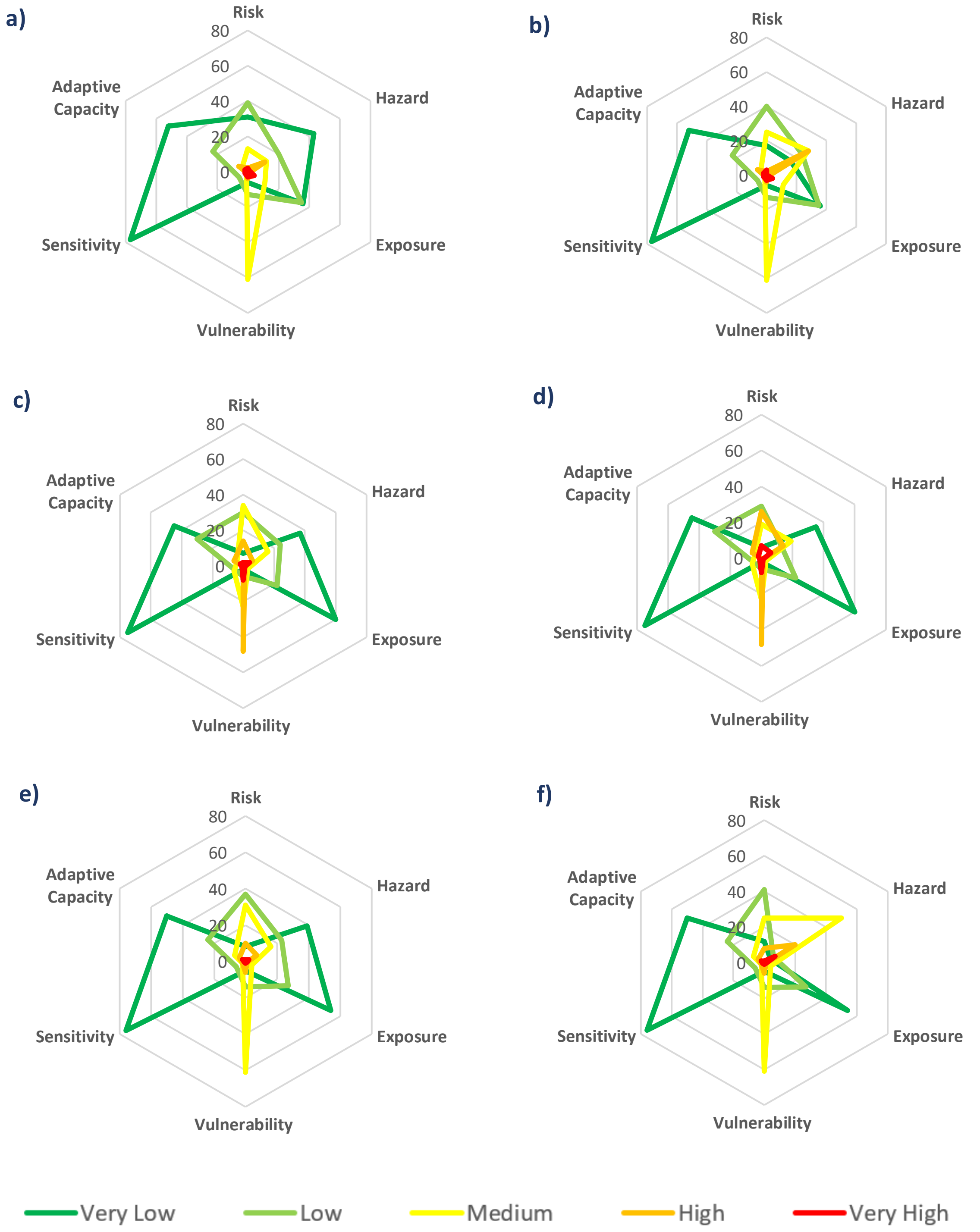

Figure 1: Radargrams representing the risk level of townships (by number) from very low to very high for: (a) aquaculture sector (2020); (b) aquaculture sector (2040); (c) inland fisheries sector (2020); (d) inland fisheries sector (2040); (e) coastal fisheries sector (2020); (f) coastal fisheries sector (2040).

Annex 4: Aquaculture Sector: State Level Risk Assessment Results

Table 1: The number of townships that received a risk level score (ranging from very low to very high) for overall risk and its sub-components for the aquaculture sector considering the present (2020) modelling scenario.

District	Level of Risk				
	Very Low	Low	Medium	High	Very High
TOTAL RISK					
Yangon	24	16	3	0	1
Ayeyarwady	5	13	5	2	1
Rakhine	2	10	5	0	0
HAZARD					
Yangon	33	6	3	2	0
Ayeyarwady	5	8	5	7	1
Rakhine	5	6	4	2	0
EXPOSURE					
Yangon	31	8	4	0	1
Ayeyarwady	2	16	5	1	2
Rakhine	3	11	2	0	1
VULNERABILITY					
Yangon	3	5	33	2	1
Ayeyarwady	2	7	13	2	2
Rakhine	1	1	15	0	0
SENSITIVITY					
Yangon	40	3	0	0	1
Ayeyarwady	21	3	0	1	1
Rakhine	16	0	1	0	0
ADAPTIVE CAPACITY					
Yangon	29	11	1	2	1
Ayeyarwady	13	7	2	3	1
Rakhine	10	5	1	1	0

Table 2: The number of townships that received a risk level score (ranging from very low to very high) for overall risk and hazard indicators for the aquaculture sector considering the future (2040) modelling scenario.

District	Level of Risk				
	Very Low	Low	Medium	High	Very High
TOTAL RISK					
Yangon	15	21	7	0	1
Ayeyarwady	1	11	11	1	2
Rakhine	1	8	7	1	0
HAZARD					
Yangon	16	16	10	2	0
Ayeyarwady	0	4	9	13	0
Rakhine	4	4	2	3	4

Annex 5: Inland Fisheries Sector: State Level Risk Assessment Results

Table 1: The number of townships that received a risk level score (ranging from very low to very high) for overall risk and its sub-components for the inland fisheries sector considering the present (2020) modelling scenario.

District	Level of Risk				
	Very Low	Low	Medium	High	Very High
TOTAL RISK					
Yangon	4	21	14	4	1
Ayeyarwady	1	2	6	11	6
Rakhine	1	0	10	6	0
HAZARD					
Yangon	32	9	2	1	0
Ayeyarwady	2	9	10	4	1
Rakhine	3	6	4	1	3
EXPOSURE					
Yangon	36	7	1	0	0
Ayeyarwady	11	12	1	1	1
Rakhine	13	3	1	0	0
VULNERABILITY					
Yangon	2	1	16	25	0
Ayeyarwady	0	3	1	14	8
Rakhine	0	2	6	9	0
SENSITIVITY					
Yangon	43	1	0	0	0
Ayeyarwady	15	4	6	0	1
Rakhine	17	0	0	0	0
ADAPTIVE CAPACITY					
Yangon	24	16	1	2	1
Ayeyarwady	13	7	3	2	1
Rakhine	8	7	0	2	0

Table 2: The number of townships that received a risk level score (ranging from very low to very high) for overall risk and hazard indicators for the inland fisheries sector considering the future (2040) modelling scenario.

District	Level of Risk				
	Very Low	Low	Medium	High	Very High
TOTAL RISK					
Yangon	5	24	8	7	0
Ayeyarwady	0	3	3	14	6
Rakhine	1	2	8	5	1
HAZARD					
Yangon	30	6	8	0	0
Ayeyarwady	1	3	9	12	1
Rakhine	4	4	2	2	5

Annex 6: Coastal Fisheries Sector: State Level Risk Assessment Results

Table 1: The number of townships that received a risk level score (ranging from very low to very high) for overall risk and its sub-components for the coastal fisheries sector considering the present (2020) modelling scenario.

District	Level of Risk				
	Very Low	Low	Medium	High	Very High
TOTAL RISK					
Yangon	6	28	8	2	0
Ayeyarwady	1	5	12	7	1
Rakhine	1	4	11	1	0
HAZARD					
Yangon	32	8	4	0	0
Ayeyarwady	3	7	12	4	0
Rakhine	4	8	0	3	2
EXPOSURE					
Yangon	31	12	1	0	0
Ayeyarwady	11	11	2	1	1
Rakhine	12	4	1	0	0
VULNERABILITY					
Yangon	3	6	34	1	0
Ayeyarwady	1	6	13	5	1
Rakhine	1	2	14	0	0
SENSITIVITY					
Yangon	43	0	1	0	0
Ayeyarwady	18	4	1	2	1
Rakhine	15	2	0	0	0
ADAPTIVE CAPACITY					
Yangon	29	12	0	2	1
Ayeyarwady	13	7	4	1	1
Rakhine	8	5	3	1	0

Table 2: The number of townships that received a risk level score (ranging from very low to very high) for overall risk and hazard indicators for the coastal fisheries sector considering the future (2040) modelling scenario.

District	Level of Risk				
	Very Low	Low	Medium	High	Very High
TOTAL RISK					
Yangon	6	27	9	2	0
Ayeyarwady	3	5	12	5	1
Rakhine	3	9	4	1	0
HAZARD					
Yangon	0	0	35	8	1
Ayeyarwady	0	2	14	10	0
Rakhine	4	4	1	2	6