Food and Agriculture Organization of the United Nations

THE RISKS AND VULNERABILITY OF THE SARDINE FISHERIES SECTOR IN THE REPUBLIC OF THE PHILIPPINES TO CLIMATE AND OTHER NON-CLIMATE PROCESSES

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Food and Agriculture Organization of the United Nations
Rome, 2021

Required citation:
Labaria, E.C., Fernandez de la Reguera, D., Poulain, F., Siar, S. and Vasconcellos, M. 2021. *The risks and vulnerability of the sardine fisheries sector in the Republic of the Philippines to climate and other non-climate processes*. Rome. https://doi.org/10.4060/cb7506en

ISBN 978-92-5-135266-3

Preparation of this document

This publication represents the proceedings of the national workshop "Risks and Vulnerability of the Sardine Fisheries Sector to Climate and other Non-Climate Processes", held in Quezon City, Republic of the Philippines, in September 2019 (Chapter 1). It also presents the baseline reports compiled for the workshop. These were produced by the Fisheries and Aquaculture Division (NFI) of the Food and Agriculture Organization of the United Nations (FAO) and were on the biophysical status (Chapter 2) and socio-economic importance (Chapter 3) of the sardine fishery of the Republic of the Philippines, as well as the projected climate change impacts on the fishery (Chapter 4). The publication concludes with a discussion of the possible climate change adaptation responses (Chapter 5), in line with the guidance of the FAO Adaptation Toolbox which categorizes action into (1) institutional adaptation; (2) livelihoods adaptation; and (3) risk reduction and management for resilience. The workshop was made possible thanks to support from the International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) of Germany, and the FAO project "Supporting member countries to implement climate change adaptation measures in fisheries and aquaculture", funded by the Norwegian Agency for Development Cooperation (NORAD).

Abstract

Climate change is projected to impact the productivity, seasonality and distribution of fisheries resources, subsequently affecting aquatic food systems and livelihoods, and ultimately threatening food security. Archipelagic countries like the Republic of the Philippines, with vast fisheries resources, are already experiencing these impacts and stand to face even worse effects in the long term as the climate continues to warm.

Under these circumstances, the sustainability of the sardine fishery – which is among the most economically important fisheries in the Philippines – is at risk. Anticipating the effects of climate change and taking appropriate action requires an understanding of the main climatic threats and risks to the fishery and related livelihoods, non-climate related stressors, and the vulnerabilities of marine ecosystems, fishers and fishing communities. It also involves the identification of potential, context-specific, and gender-responsive adaptation options that would mitigate these risks.

This publication documents the proceedings of the national workshop "Risks and Vulnerability of the Sardine Fisheries Sector to Climate and other Non-Climate Processes" held in Quezon City, Republic of the Philippines, in September 2019, and attended by fisheries stakeholders from around the country (Chapter 1). It also presents the baseline reports compiled for the workshop by FAO's NFI. These were on the biophysical status (Chapter 2) and socio-economic importance (Chapter 3) of the sardine fishery of the Republic of the Philippines, as well as the projected climate change impacts on the fishery (Chapter 4). The publication concludes with a discussion of the possible adaptation responses (Chapter 5) in line with the guidance from the FAO Adaptation Toolbox which categorizes action into (1) institutional adaptation; (2) livelihoods adaptation; and (3) risk reduction and management for resilience.

The workshop conducted and the literature developed served as an exercise and starting point for the fisheries sector in the Republic of the Philippines and other stakeholders to improve the framing of climate-related risks to, and emerging trends in, fisheries livelihoods. They also provided an opportunity to deliberate on appropriate management responses and adaptation actions specifically for the sardine fishery. Lessons learned from this exercise may be beneficial in understanding and managing other types of fisheries threatened by climate change.

Contents

Acknowledgements

This publication is made possible with the support of the Integrating Agriculture in National Adaptation Plans (NAP-Ag) programme of FAO and United Nations Development Programme (UNDP). It was funded by the IKI of the German BMU and the FAO project "Supporting member countries to implement climate change adaptation measures in fisheries and aquaculture", funded by NORAD.

The editors would like to acknowledge Wilfredo Campos, Alexanra Bagarinao-Regalado and Didi Baticados, as FAO expert investigators of the baseline reports included in this publication. They would also like to thank the following for their contribution towards the organization of the national workshop and the preparation of this document: Paulo Marco Caparas and Marikris De Guzman (FAO Country Office in the Republic of the Philippines), Director U-Nichols Manalo and Perla Baltazar (Department of Agriculture), Lainie Baraocor (Bureau of Fisheries and Aquatic Resources) Jean Mea and Heizel Rapista (event documentors), Claire Ward (editor) and Zoe Brandizzi (graphic designer).

Abbreviations and acronyms

AAGR	average annual growth rate
ARMM	Autonomous Region in Muslim Mindinao
BAS	Bureau of Agricultural Statistics
BFAR	Bureau of Fisheries and Aquatic Resources
BFAR DRR/M	Bureau of Fisheries and Aquatic Resources' Disaster Risk Reduction and Management Strategic Framework
CAR	Cordillera Administrative Region
CCDRRM	Climate Change Disaster Risk Reduction Management
CFV	commercial fishing vessel
CMIP5	Coupled Model Intercomparison Project
CO2	carbon dioxide
CPUE	catch per unit effort
$GtCO_2$-eq	CO_2-equivalent
CRM	coastal resource management
DA-BFAR	Department of Agriculture – Bureau of Fisheries and Aquatic Resources
DBEM	dynamic bioclimate envelope model
DENR	Department of Environment and Natural Resources
DILG	Department of Interior and Local Governments
DOST-PAGASA	Department of Science and Technology's Philippine Atmospheric, Geophysical and Astronomic Services Administration
DSS	decision support system
DSWD	Department of Social Welfare and Development
EEZ	exclusive economic zone
ENSO	El Niño–Southern Oscillation
FAD	fish aggregating device
FARMCs	Fisheries and Aquatic Resources Management Councils
FAO	Food and Agriculture Organization of the United Nations
FGD	focus group discussion
FMAs	fisheries management areas
GHG	greenhouse gas
GSI	gonado-somatic index
HH	household
IKI	International Climate Initiative
IEC	information, education and communication
IPCC	Intergovernmental Panel on Climate Change
ISDA	In-glass Sardine Association
JOA	Joint Administrative Order
LECZ	low elevation coastal zones
LGU	Local Government Unit
LME	large marine ecosystem
MC	Memorandum Circular
MCP	maximum catch potential
MPA	marine protected area

MSY	maximum sustainable yield
NAP-Ag	Integrating Agriculture into National Adaptation Plans Programme
NAPs	National Adaptation Plans
NCR	National Capital Region
NDC	nationally determined contribution
NFI	FAO Fisheries Division
NGA	non-government agencies
NGO	non-governmental organization
Norad	Norwegian Agency for Development Cooperation
NSAP	National Stock Assessment Programme
NSMFP	National Sardine Management Framework Plan
NSO	National Statistics Office
NZP	Northern Zamboanga Peninsula
PAGASA	Philippine Atmospheric, Geophysical and Astronomic Services Administration (of the Department of Science and Technology)
PSA	Philippine Statistics Authority
PFDA	Philippine Fisheries Development Authority
RCP	representative concentration pathway
RA	Republic Act
RC	realized catch
SAG	Scientific Advisory Group
SDGs	Sustainable Development Goals
SL	standard length
SST	sea surface temperature
SSTA	sea surface temperature anomaly
TESDA	Technical Education and Skills Development Training
TC	tropical cyclone
TL	tail length
TURFs	territorial use rights for fisheries
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Chapter 1

The risks and vulnerability of the sardine fisheries sector to climate and other non-climate processes: National workshop report

1.1 INTRODUCTION

The workshop on the "Risks and Vulnerability of the Sardine Fisheries Sector to Climate and other Non-Climate Processes" took place in Quezon city, Republic of the Philippines, on 18 and 19 September 2019. The workshop was funded by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) with the support of the Norwegian Agency for Development Cooperation (NORAD) under the following relevant projects:

The Integrating Agriculture in National Adaptation Plans (NAP-Ag) Programme is a multi-year initiative funded by IKI and features a unique collaboration between the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Programme (UNDP). The global programme seeks to enhance:

- institutional capacities and processes for operationalizing climate response strategies in the sector;
- access to international climate finance sources such as the Global Environment Facility and the Green Climate Fund; and
- more strategic allocations of national budgets earmarked for adaptation investments.

It is implemented in Nepal, Kenya, Philippines, Thailand, Uganda, Uruguay, Viet Nam and Zambia, and most recently in Colombia, Gambia and Guatemala.

The project "Supporting member countries to implement climate change adaptation measures in fisheries and aquaculture" (GCF/GLO/959/NOR) is a 12-month project funded by Norad and executed by FAO. The aim of the project is to improve country capacity to develop and implement climate change adaptation plans and actions that promote socio-economic development, with specific attention to poverty reduction and food security in the fishery and aquaculture sector. Expected benefits include strengthened resilience to climate change and improved climate change plans, including National Adaptation Plans (NAPs) and Nationally Determined Contributions.

FISHERIES ADAPTATION

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gas are the highest in history. Recent climate changes have had widespread impacts on human and natural systems on all continents and across the oceans (IPCC, 2013). A recent FAO report, *Impacts of climate change on fisheries and aquacultzure: synthesis of current knowledge, adaptation and mitigation options* (FAO, 2018) indicates that climate change will lead to significant changes in the availability and trade of fish products, with potentially important geopolitical and economic consequences, especially for those countries most dependent on the sector. Building on this report and related literature, the FAO Fisheries Division (NFI) has produced background documents on the projected impacts of climate change on sardine fisheries in the Republic of the Philippines and implications for management and adaptation responses.

WORKSHOP OBJECTIVES

The objectives of the national workshop were to convene key government, academic and civil society partners to:

- present projected climate change impacts on sardine fisheries and dependent livelihoods and discuss application to other species;
- discuss current vulnerabilities of the sardine fisheries to climate change, as well as biophysical and socio-economic risks and impacts;
- present related assessment tools and studies;
- present the FAO Adaptation Toolbox; and
- map existing interventions and identify adaptation needs for the fisheries sector.

PARTICIPATION

A total of 48 participants from 19 government, non-government and international development organizations were represented at the workshop. The list of participants can be found in Annex 1.1.

WORKSHOP OVERVIEW

The first day of the workshop was focused on the climate change impacts in the Republic of the Philippines and their effects on the marine ecosystems and coastal communities, in particular in the sardine fisheries. Studies describing the sardine fisheries in the Republic of the Philippines, their socio-economic importance and their climate and non-climate related stressors were presented.

On the second day, the National Sardines Management Framework Plan, the sardine fisheries' priorities in the context of climate change, and the vulnerability of the sardine sector in the Republic of the Philippines, were discussed. Potential responses through the implementation of the FAO Adaptation Toolbox were presented and further discussed with the participants during a group exercise.

The programme of activities of the workshop can be found in Annex 1.2.

1.2 WORKSHOP PROCEEDINGS

Integrating Agriculture into National Adaptation Plans Programme, Philippines: Background, fisheries in country national climate change policy, by Carlie Labaria, Food and Agriculture Organization, Philippines

NAP-Ag is a global programme to identify and address climate change adaptation measures for the agriculture sectors in relevant national planning and budgeting processes, through the formulation and implementation of a NAP.
NAP-Ag has four outcome areas:

1. to strengthen technical capacity and institutions on NAPs;
2. to develop integrated roadmaps for NAPs;
3. to improve evidence-based results for NAPs; and
4. to promote advocacy and knowledge-sharing on NAPs.

The programme follows a prescribed implementation logic and strategies, including:

- enhancing regional and global dialogues through peer-to-peer exchanges;
- strengthening gender-responsive adaptation planning;
- stocktaking and prioritization of adaptation activities;
- creating synergies with ongoing projects; and
- unlocking international climate finance.

In alignment with the outcomes and strategies, the programme has accomplished, among other things:

- the development of forecast products for the agriculture sector with the Department of Science & Technology's Philippine Atmospheric, Geophysical and Astronomical Services Administration (DOST PAGASA);
- the inclusion of an outcome area on adaptation in the Agri-Fisheries Modernization Plan;
- funding acquisition for scaling the Adaptation and Mitigation Initiative in Agriculture in villages;
- mainstreaming a gender lens; and
- the establishment of the Department of Agriculture's Disaster Risk Reduction and Management Operations Centre.

Introduction to workshop objectives in the context of climate change adaptation planning, by Florence Poulain, Food and Agriculture Organization, Fisheries Division

The Intergovernmental Panel on Climate Change (IPCC) issued a statement in 2017, stating that the warming of the climate system is unequivocal. This statement is further supported by evidence, such as increasing average global air and ocean temperatures, rising sea levels and widespread melting of snow and ice. The biophysical changes resulting from global warming have effects on production ecology; fishing, aquaculture and associated post-harvest operations; communities and livelihoods; and wider society and the economy. Given the impacts of climate change on the global fish catch, it is important to implement aggressive mitigation efforts to achieve a more favourable maximum catch potential.

The national workshop aimed to convene key government, academia and civil society partners to:

- identify and agree on the main threats and risks to the sardine fishery and related livelihoods, using the best available knowledge, model projections and stakeholders' views;
- identify potential adaptation options for each of the main threats that would mitigate these risks, including institutional and livelihoods options and risk reduction and management mechanisms; and
- carry out a preliminary appraisal of the identified options.

The adaptation planning cycle provides a guide to identify the main threats and risks to the sardine fishery and related livelihoods, as well as to identify potential adaptation options to mitigate these risks. It starts with identifying problems and objectives and assessing current and future risks. A combination of a top-down and a bottom-up approach in assessing current risks is important for climate adaptation.

Assessment of current policies, strategies and socio-economic context is needed for contextual analysis of sector development. The next steps in the cycle are to identify adaptation options, appraise these options, and implement them. The FAO Adaptation Toolbox, which serves as a guide to select and implement adaptation activities, identifies three overarching categories of adaptation activities:

1. institutional adaptation;
2. livelihoods adaptation; and
3. risk reduction and management for resilience.

Identifying adaptation options should consider the place, context, transboundary issues, and coordination measures. Adaptation should also be viewed as an ongoing and iterative process. The adaptation activities to be implemented should also be monitored and evaluated.

Climate trends and projections: Impacts on coastal communities, by Jorybell Masallo, Department of Science & Technology's Philippine Atmospheric, Geophysical and Astronomical Services Administration, Climate Monitoring and Prediction Section, Climatology and Agrometeorology Division

Observed globally, climate change has far-reaching impacts, such as increase in global average surface temperature, changes in average precipitation, global mean sea level rise, and changes in the frequency of extreme events. Various climate trends have been recorded in the Republic of the Philippines. For 65 years (1951 to 2015), a 0.68 °C increase in annual mean temperature in the Republic of the Philippines was observed. Increasing trends in annual and seasonal total rainfall were found in central parts of Luzon, the eastern section of Visayas and the northeastern and southwestern sections of Luzon. In contrast, northern sections of Luzon, western sections of Visayas and central and western sections of Mindanao show an increase in drying trends. The trend also shows an increasing number of hot days and decreasing cold days in the country. The frequency of extreme rainfall events is also increasing, while the number of intense tropical cyclones has increased slightly.

The increase in sea level rise and total rainfall in specific parts of the Republic of the Philippines increases the vulnerability of the country as it is highly susceptible to flooding and inundations, sea level rise, storm surges and ground movement. Climate change impacts on fisheries include:

- ocean acidification;
- high sea surface temperature;
- a dramatic change in distribution and biomass of fish and seafoods;
- coral bleaching;
- decreased calcification; and
- triggering of algal blooms which cause red tides and kill fish.

To build resilience among stakeholders, climate mitigation and adaptation actions need to be implemented. Mitigation actions can be broadly categorized into:

- improve and develop technologies to increase energy efficiency, use renewable energy and capture and store carbon;
- apply regulations and standards that support low fossil fuel use;
- use instruments, such as carbon finance and markets, to help reduce emissions; and
- change behaviour and lifestyle.

Projected impacts of climate change on fisheries habitat sustainability, by Rollan Geronimo, Marine Environment and Resources Foundation, Inc./Fish Right Programme

The study on the impacts of climate change on fisheries habitat sustainability, an output of the Fish Right Programme of the Republic of the Philippine government and United States Agency for International Development, proved that the ocean around the country is warming rapidly. Climate projections show ocean conditions are warmer with lower salinity. The study also estimates a 15 percent to 30 percent projected reduction in suitable habitat as a result of climate change, with sea surface temperature as a major driver.

At least eight species experienced conditions exceeding current known exposure levels (climate-sensitive species). To further improve understanding of climate change impacts on sardine fisheries, the following can be done:

- incorporate spatial information in catch monitoring;
- calibrate satellite information with local data and collect more oceanographic and environmental data;
- collaborate with academic and research institutions for high resolution climate change projection models; and
- improve understanding of fish populations and ecosystems; and monitor climate-sensitive species.

Impacts of climate change on* Sardinella lemuru *in the exclusive economic zone of the Philippines and potential resources, by Diana Fernandez, Food and Agriculture Organization, Fisheries Division

Under the representative concentration pathway (RCP) 2.6 scenario (rigorous mitigation scenario with low greenhouse gas emissions), the projected maximum catch potential of Sarinella lemuru in the exclusive economic zone (EEZ) of the Republic of the Philippines is not likely to decrease by 2050, while the overall projected potential catch of all species combined might show some decrease. In contrast, under RCP8.5, or a business-as-usual scenario, the projected maximum catch potential of all species in the Republic of the Philippine's EEZ is likely to decrease by 2050, with Sardinella lemuru decreasing in particular on average up to 30 percent.

In the projections and scenarios used, the average decrease in maximum catch potential in the Republic of the Philippines is larger than the average change worldwide. It is important to contain the global temperature increase to no more than 1.5 °C above pre-industrial levels. To guarantee the sustainability of the fishery of Sardinella lemuru in the Republic of the Philippines' EEZ, and considering the variety of results of projections on potential catch by mid-century, a flexible management plan is required. Such a plan should foresee immediate actions, including addressing the current state of resources, prepare for future changes (i.e. planning, monitoring, research), and set out medium to long-term actions to adapt to future changes.

Philippine sardine fisheries: Status of stocks, stressors, threats and measures for sustainability, by Wilfredo Campos, OceanBio Lab, College of Arts and Sciences, University of the Philippines Visayas Miag-Ao, Iloilo

Since 2009, there has been a decline in the production of sardines in the Republic of the Philippines. Sardines constitute 16.8 percent of the total marine fisheries capture, with an average production of 344 000 tonnes from 2013 to 2017. Sardinella gibbosa in the Visayan Sea were much smaller than fish in stocks elsewhere, while Sardinella lemuru mature at a larger size in the Ticao Pass/San Bernardino Straight, which could be a result of environmental conditions. Identified threats to sustainability include:

- encroachment of commercial vessels in municipal waters;
- absence of a programme to regulate open access;
- inadequate support to the industry from the national government;
- limited access and availability of data useful for management;
- lack of local capacity to manage fisheries;
- limited participation of science and academia;
- high spoilage and wastage rates (municipal level); and
- inefficient market chain (municipal level).

To address these sustainability threats, the following measures should be implemented:

- the application of a closed season during peak spawning season;
- banning gear targeting fry and early juveniles; and
- reducing the fishing effort of the communities and municipalities.

Different climate change drivers such as sea surface temperature, El Niño–Southern Oscillation (ENSO), rainfall, storm frequency and sea level rise, are expected to have different impacts on fisheries. Increases in ocean temperature result in distortions in current flow and changes in hydrography, affecting larval transport. The ENSO is anticipated to increase sardine production off Zamboanga Peninsula (due to upwelling) and decrease small pelagic catch rates in the Visayan Sea (shallow). At the same time, it could possibly result in a smaller hatching size for Sardinella gibbosa and significant variability in early growth in the Zamboanga Peninsula. Rainfall may increase stratification and decrease upwelling while reducing the drying capacity of fish processors. Increased storm frequency and sea level rise forces fishers along the coast to relocate, poses vessel safety concerns, and reduces the number of effective fishing days.

Climate change and the sardine fishery sector in the Philippines, by Didi Baticados, Integrated Services for the Development of Aquaculture and Fisheries, Inc.

Fisheries, specifically the sardine fishery, provide significant socio-economic benefits, livelihood and employment to Filipinos. In 2017, fisheries accounted for 1.2 percent (PHP 197.23 billion) of gross domestic product. Of the total marine fisheries production in 2017, sardine comprised 17 percent, or 326 965.63 tonnes. In 2015, about 2.38 percent of the Republic of the Philippines' population of 15 years and over were economically active in sardine fisheries. The number of commercial fishers harvesting sardine is about 24 962, while the number of those employed in ancillary services is undetermined. The sardine industry in Region 9, the sardine capital of the Republic of the Philippines, is estimated to be a PHP 20 billion industry with 50 000 workers, as claimed by former Department of Agriculture Secretary, Emmanuel Piñol.

Given that the fisheries sector is heavily impacted by climate change, climate hazards combined with anthropogenic factors pose a serious threat to livelihood, properties, lives, and coastal ecosystems, including sardine-producing communities. Climate hazards include temperature anomalies, ocean acidification, sea level rise and extreme weather. Anthropogenic factors include pollution, overfishing, blast fishing and climate change, among others. Exposure to these may result in fish disturbance and migration, and expose coastal communities to higher levels of threat to life and properties, considering that coastal communities often find it difficult to adapt due to a lack of knowledge and information about climate change.

Recommendations to address the identified gaps in sardine-producing communities include:

- co-management for municipal and commercial fishers to address intensified competition for resource extraction as a result of an "open access" regime;
- livelihood diversification and provision of training by the Technical Education and Skills Development Authority to resolve a lack of livelihood opportunities;
- an information, education, and communication (IEC) campaign in coastal communities to enhance knowledge and awareness of climate change impact;
- enhance research capabilities of the Bureau of Fisheries and Aquatic Resources' (BFAR's) research arm on climate change aspects affecting fisheries; and
- strengthen institutional partnerships using Fisheries Management Areas (FMAs) as platforms to address fisheries issues and climate change.

National Stock Assessment Programme, by Francisco Torres, Jr., National Fisheries Research and Development Institute

The National Stock Assessment Programme (NSAP) was conceptualized to create standardized and continuous information fundamental to fisheries management, and to address the institutional capacity of regional field units to conduct resource assessment studies in their jurisdiction. Through a special order from the Secretary of the Department of Agriculture, the programme was started in June 1997, with long-term objectives to develop and institutionalize the capability of the region in resource assessment, management and development. The programme also wanted to generate reliable data as a basis to design policies for the management and conservation of the country's marine resources, to attain sustainable development and exploitation. Short-term objectives of the programme include:

- to determine the trend of seasonal distribution, relative abundance, size and species composition of the major marine resources in each fishing ground;
- to provide estimates of population parameters of the major marine resources in each fishing ground; and
- to complement the Philippine Statistics Authority in the generation of fisheries statistics.

NSAP activities include fish catch monitoring in more than 700 fish landing centres across the country, training of technical staff for skills development and improvement, and planning workshops. Other activities include the publication of study reports, participation in scientific conferences, and participation in collaborative research and reporting.

NSAP has a database application to store and manipulate data which is installed in the different NSAP regional office workstations and synchronized to the network server of the BFAR central office. A remote access service connection is available for transferring the data and other information. The NSAP intranet website hosts important information, trivia, updates, pictures, staff lists and regional fisheries profiles, all relating to the NSAP.

Vulnerable groups: Gender and climate change, by Susana Siar, Food and Agriculture Organization, Regional Office for Asia and the Pacific

The United Nations Framework on Climate Change Synthesis report on the differentiated impacts of climate change on women and men; the integration of gender considerations in climate policies, plans and actions; and progress in enhancing gender balance in national climate delegations highlights the importance of considering the differentiated impacts of climate change in climate policies, plans and action, including through the use of gender analysis and sex-disaggregated data.

The fishing sector is male dominated, while women are mostly engaged in secondary activities in fisheries and aquaculture. The lack of sex-disaggregated statistics make women's contribution invisible, not measured and not valued. With or without climate change, gender inequality affects:

- access to fisheries resources;
- information
- extension services;
- financial services;
- adequate infrastructure;
- productive resources;
- decision-making processes; and
- social security benefits.

A person's vulnerability can be influenced by gender, age, socio-economic status, ethnicity and ability or disability. Climate adaptation actions in the fishery sector should address and not worsen existing gender inequalities, consider intersectionality, and examine the whole fish supply chain to ensure that no one is left behind.

Potential responses to climate change: Management implications, by Marcello Vasconcellos, Food and Agriculture Organization, Fisheries Division

The FAO Adaptation Toolbox includes different adaptation responses, such as institutional adaptation, livelihoods adaptation, and risk reduction, which can be used in conjunction with the objectives of a fisheries management plan.

Small pelagic fish are important fisheries resources worldwide, comprising approximately 15 percent of global fisheries catches, according to FAO. Climate variability and change affect productivity and distribution of pelagic resources. The predicted geographic shifts in fish distribution driven by climate change over the coming decades can become a potential for conflict over newly shared resources. Among others, distribution shifts can affect the defined geographic boundaries and access of fishers, exacerbate resource overfishing, and affect the perception of stock status and management advice resulting from stock assessment.

Thus, given the real and potential challenges posed by climate change to the fishery sector, managing fisheries requires making decisions under conditions of uncertainty. The precautionary approach and adaptive management approach are recommended in this context. The former approach emphasizes caution, pausing and review before leaping (“err on the side of caution”), while the latter is about learning by doing.

To cope with variability and changes in productivity, specific approaches can be used. The first is to monitor and adjust if there is an enhanced understanding of factors controlling fluctuations in abundance and production. This can be used to forecast stock productivity and adjust fishing rates accordingly. Tactics include, allowing higher fishing mortalities in a favourable situation and lower fishing mortalities under unfavourable conditions, as well as decreasing fishing mortality during a favourable period to allow for resource recovery. The second is to apply robust measures to uncertainties if there is little prospect that uncertainties in the factors affecting stock productivity will be reduced. It is better to adopt robust management strategies to the environmental changes affecting stock productivity. A fixed exploitation rate is the suggested tactic under this approach.

Guidelines on fisheries management processes include:

- consider actions to avoid undesirable outcomes in case of unfavourable conditions;
- ensure actions are broadly accepted through consultations with stakeholders;
- set targets commensurate with the level of uncertainty;
- use contingency rules to cope with major adverse events, define what robust measures to use to mitigate uncertainties and apply redundancy in choosing management measures;
- ensure regular assessment of stocks, fisheries and environmental conditions; and
- periodically re-evaluate and adapt the level of precaution in the management system.

A fishery management system that is robust when dealing with the effects of climate change on productivity will require a decrease in fishing mortality in the short to medium term and a long-term strategy to maintain relatively constant exploitation rates, within sustainable precautionary levels. The establishment of FMAs can be a good strategy in the Republic of the Philippines to cope with shifts in national waters.

National Sardines Management Framework Plan, by Kima Karla Cedo, Bureau of Fisheries and Aquatic Resources

In 2007, BFAR drafted the Sulu Sea Sardine Management Plan to identify the maximum sustainable yield and cap fishing effort at the level that occurred on 31 December 2006. In 2017, a technical working group was created and in 2018, a forum and workshops were organized and NSAP inputs were incorporated. In the same year, the plan was developed and it was adopted in 2019. The vision is to have a sustainable and equitably shared sardine fishery that contributes to food and income security through responsible management. The six major species of sardines in the Republic of the Philippines are Sardinella lemuru, Sardinella gibbosa, Sardinella albella, Amblygaster sirm, Escualosa thoracata and Sardinella fimbriate. In the past 15 years, the country's production of sardines averaged about 333 743 tonnes, or 15 percent of the total marine capture fisheries.

Various fisheries and ecological, socio-economic and human well-being, and governance issues facing the sardine sector were identified:

Fisheries and ecological issues include:

- inadequate science-based studies on the stock assessment within municipal waters;
- decreasing production/productivity/catch per unit effort or catch rates; and
- the need for more studies on the reproductive biology and ecology of sardines in various areas, as well as climate change impact studies.

Socio-economic issues consist of:

- post-harvest losses during peak season;
- limited market for excess production during peak season;
- inadequate livelihood programmes for fishers;
- low awareness of and compliance with fisheries policies related to sardine management; and
- lack of capacity to access financial credit programmes.

Governance issues involve:

- weak institutional capacity and mechanisms to implement national fisheries management programmes;
- encroachment of commercial vessels in municipal waters;
- weak IEC; and
- too much political intervention, among others.

The National Sardines Management Framework Plan has three primary goals:

1. improved science-based indicators for the sustainability of sardine stocks;
2. improved distribution of benefits among sardine fisher communities; and
3. strengthened science-based management for sustainable sardine fisheries.

The NSAP of the Republic of the Philippines underwent a series of workshops and national deliberation.

Fisheries vulnerability assessment of the sardines sector in the Philippines using FishVool, by Mudjekeewis Santos, National Fisheries Research and Development Institute

FishVool is a vulnerability assessment tool for capture fisheries and aquaculture, which supports existing vulnerability assessments. In comparison, FishVool is more targeted towards the agriculture sector, and applies a participatory approach in data gathering among stakeholders and fishers. The tool follows the IPCC framework of conducting vulnerability assessments that examine exposure, sensitivity and adaptive capacity to determine the vulnerability status.

The sensitivity rubrics for scoring include:

- a comparison of catch rate 20 years ago;
- average length of fish catches;
- dependence on resource;
- household age structure; and
- health conditions.

Exposure rubrics include the fishing ground, household and community, based on annual occurrence.

Addressing adaptive capacity can help improve the resilience of communities. Adaptive capacity rubrics include:

- annual income from fishing;
- awareness of climate change;
- access to information;
- adaptive strategy;
- literacy;
- gear modification and replacement; and
- programmes or support systems against climate change.

In the Republic of the Philippines, findings using FishVool show that Zamboanga city has higher exposure values because it is frequently impacted by localized typhoons. DOST-PAGASA, the weather bureau of the Republic of the Philippines, projected that seasonal temperature, rainfall and frequency of extreme events have increased. The increase in temperature and increasing rainfall are already affecting local fishers and the community. According to fishers who were interviewed, increasing numbers of commercial fishing vessels have resulted in decreasing catch rates for fishers over the past 20 years. The sardine sector in Zamboanga city has low adaptive capacity compared to the tuna sector in General Santos, which may be attributed to low awareness and few sources of climate change-related information and adaptive strategies.

BFAR Climate Change Disaster Risk Reduction and Management Strategic Framework, by Lainie Baraocor, Bureau of Fisheries and Aquatic Resources

The Climate Change Disaster Risk Reduction Strategic Framework of BFAR provides a general framework that is overarching in terms of implementation among different commodities and projects. The framework is intended to facilitate implementation of policies, laws, rules and regulations, such as the Climate Change Act of 2009, the Philippine Disaster and Risk Reduction Management Act of 2010, and other related memoranda and orders on climate change disaster risk reduction management (CCDRRM) activities of the Bureau.

It covers prevention and mitigation, preparedness, response, and rehabilitation and recovery, while FishVool assesses the suitability and vulnerability of a given fishing area. One limitation of the framework is the lack of profiling to determine the sectors affected by climate change as it is absent in the CC-DRRM guidelines.

Sardine wastage: The case of Bulan, Sorsogon, by Benjamin Francisco, Bulan Fish Port

Each day, a total of 22 tonnes of fish lands in the Bulan fish port in the province of Sorsogon. Established in 1996, the port is managed by the Fisheries Development Authority. There are at least 78 traders, 6 413 workers and 1 541 registered fishing vessels in the area, with fishing crew usually consisting of 14 fishers per boat. The peak fishing season for sardines (during the monsoons) yields a catch rate that averages 30 to 40 tubs per boat (35 kg per tub), while the catch rate range is 5 to 15 tubs during a lean season.

There is usually no wastage of sardine in the port under normal circumstances because bagoong (fish paste) buyers buy disfigured sardines to make fish paste. Severely mutilated fish are discarded or used as feed in backyard piggeries. However, in November 2018, fishers experienced an upsurge in catch rate which was eventually spoiled as they refused to sell at an “insulting” price to buyers who allegedly conspired to trim the price down from PHP 20/kg to PHP 4/ kg. This situation raised issues related to deficient ice supply and lack of canneries in the province, resulting in localized oversupply, as well as the lack of fish paste processors due to stringent requirements by the Food and Drug Administration and the high histamine content of Philippine fish paste/sauce, thus failing export standards.

To address these issues, it is important to craft a responsive, tailor-made micro-enterprise programme for sardines to:

- add value for small traders;
- mobilize a network of micro financing institutions to develop investment profiles and business plans;
- develop and demonstrate technical tools to improve the fish paste industry and make it more internationally competitive; and
- promote the province of Sorsogon as a viable venue for sardine canneries.

Gender sensitive value chain analysis of the seaweed industry in Albay and Sorsogon, by Thea Bohol, Food and Agriculture Organization, Republic of the Philippines

Value chain analysis is the process of examining each step of the production chain to understand its structure and functioning. It identifies actors, functions and relationships at each stage, determining the decision-makers in every step of the production chain, and identifying value adding activities, flow of goods, and information and finance through the chain. This is used by donors and development assistance agencies to better target their support and investment in various areas, such as income distribution and equity among value chain participants.

The study aims to identify and understand the underlying gender constraints that may inhibit women's participation in the seaweed value chain. Specifically, the study:

- maps out the participation of women in the entire seaweed value chain;
- identifies gender constraints in accessing and controlling productive resources; and
- enumerates benefits in removing gender barriers in the seaweed industry.

Using a combination of classical and participatory vulnerability and capacity assessment, the study found several gender-related constraints, such as:

- a lack of transport facilities limiting women's interaction with traders and consolidators;
- unpaid care work;
- double burden in the community; and
- receiving small implements but not boats, which are generally granted to men.

The study also revealed gender-related opportunities. Women are very active in the value chain and often manage cooperatives. They have savings from selling seaweed and have access to implements and training with BFAR.

To remove gender barriers, there is a need to redistribute unpaid care work and address the double burden of women and traditional gender roles. There should be more regulation of the rate of buying and selling, and traders and consolidators. Further improvements in the method used by government agencies in compiling a master list of practices, transport infrastructure and seaweed processing plants should also be implemented.

Potential responses: FAO Adaptation Toolbox, by Florence Poulain, Food and Agriculture Organization, Fisheries Division

The FAO Adaptation Toolbox has three types of overarching adaptation activities: institutional adaptation, livelihoods adaptation, and risk reduction and management for resilience.

Institutional adaptation considers public policies, legal frameworks, institutional frameworks and management and planning. Livelihood adaptation is categorized into "within sector" and "between sectors". Risk reduction and management for resilience involves aspects on pooling and risk transfer, early warning, risk reduction, and preparedness and response.

In implementing adaptation activities, the challenges include the decision time scale, changing risk levels, risk of lock-in, uncertainty, and economic and other climate stressors. Adaptation type also varies with risk profile since risks change over time.

1.3 GROUP WORK

As part of the workshop, a group exercise was conducted to identify climate change adaptation needs for the fisheries sector.

Participants were grouped into three categories: municipal fishers, commercial fishers, and science and policy experts. Following the guide provided by the adaptation planning cycle, each group identified current and future climate-related risks and emerging trends in the fisheries sector and related livelihoods (Table 1.1 to 1.3).

Applying the FAO Adaptation Toolbox and considering different time frames, participants successfully identified potential adaptation options for each of the main threats, including institutional and livelihoods options and risk reduction and management mechanisms, and were able to carry out a preliminary appraisal of the identified options.

Overall, the following will increase resilience in the sector:

- good governance;
- broader dissemination of the ecosystem approach to fisheries management;
- the implementation of the FMAs, Marine Protected Area (MPA) networks and policies related to resources management;
- ecosystem restoration;
- supporting livelihoods and enhancing social components;
- capacity building and skills development;
- sector diversification; and
- risk reduction and management.

Victorino Delos Reyes Jr. of the Municipal Fisheries and Aquatic Management Council, presents the output of the Municipality group

Table 1.1

Climate related risks and issues identified by Group 1: Municipality (participants included representatives of Bureau of Fisheries and Aquatic Resources, local government units, non-governmental organizations and fishers)

1. Lack of education of fishers, for example, fishing of juvenile species could lead to coastal habitat destruction.
2. Presence of marine litter, specifically plastic litter; participant stated that crab fishing left no plastic litter prior to fishing with nets; plastic litter from other municipalities were washed up at Bulan; Bulan was called the catch basin of plastic litter from Masbate and Samar.
3. Human settlement or presence of informal settlers along the seashore; presence of open defecation due to lack of proper shelter.
4. Erosion of shoreline; reducing coastline; sea level rise and shrinking coastline. Soil erosion could be from the conversion of forest area into farmland for

corn plantation; sea surface temperature increasing even during wet season, especially in island barangays (villages or suburbs).
5. Fishing using lift net method led to catching juvenile fish; political will and governance issue was also cited in Ajuy as a reason for juvenile fishing and other issues.
6. Intensified storms; illegal fishing; conversion of agricultural land into subdivisions; no provision for safety gear for fishers due to lack of budget.

Ephrime Metillo of Mindanao State University – Illigan Institute of Technology, presents the first part of the Science & Policy group's output

Table 1.2
Climate related risks and issues identified by Group 2: Science & Policy (participants included representatives of the Bureau of Fisheries and Aquatic Resources, regional directors, academia, Department of Environment and Natural Resources and the Climate Change Commission

1. Good governance is important; ecosystem approach to fisheries management with climate lens; implement FMAs and establish a MPA network. The project, through the Department of Environment and Natural Resources (DENR) is facilitating a Joint Memorandum Circular (JMC) on MPA network. A JMC will put forward concrete policy on resource management.
2. Livelihood support and skills development, e.g. as a learning module in the senior high school levels, to improve skills.
3. Capacitation in resources management and fishing cited as long-term adaptation. Resources and human resources are challenges that need support from the development partners to support national and local government units.
4. Fishers need environment-friendly fishing methods.
5. The future is still changing and there are uncertainties, but it was stressed that adaptive mechanisms should not be limiting.

Roberto Valerio of Industrial Group of Zamboanga, presents the output of the Commercial group

Table 1.3
Climate-related risks and issues identified by Group 3: Commercial fisheries (participants included representatives of industry and fish port staff).

1. Cited the possibility of next phase wherein FAO expressed its support. The workshop was a learning experience for FAO; interesting and enriching for the organization.
2. Importance of looking at the impact of the other activities, e.g. farming in upland areas that worsens the situation in coastal areas. Need to be mindful of the adaptation actions of other sectors that may have an impact on the fishery sector.
3. Commercial fishers in Zamboanga are in a protected watershed area; expressed interest in protected area management.

1.4 CONCLUSIONS

The Republic of the Philippines, as a large archipelago with a very long coastline and numerous islands, is highly vulnerable to climate change. Several changes in the country's marine ecosystems are already evident due to the impacts of climate change, and future projections indicate that these changes will be accentuated in the long term, and will affect the fisheries and aquaculture sector. Vulnerability to climate change impacts will vary across regions according to differential exposure and social vulnerability. There is a need to take into account the potential differential vulnerabilities within communities (e.g. gender, age, socio-economic status, etc.) and to conduct more research and generate information needed to enhance understanding of vulnerabilities, and examine the whole fish supply chain to ensure that no one is left behind. In the Republic of the Philippines, Region IX (Zamboanga) is particularly important due to its reliance on sardine and its social vulnerabilities.However, the majority of sardine-dependent communities in the country are poor, showing vulnerability with at least one of the indices on social vulnerability, and should be addressed accordingly.

The National Sardines Programme Management Framework is being finalized, but climate resilience had not yet been included by the time the workshop took place. A proposal was made to include climate resilience in the framework and to also take note of the status of the fish stock. A robust fishery management system able to mitigate the effects of climate change on productivity would require a short to medium term decrease in fishing and a long-term strategy to maintain sustainable exploitation rates in the future. Fisheries management also needs to be prepared to cope with the potential implications of distribution shifts (including changes in resource boundaries, access of fleets, stock assessment) and evaluate the need for inter-jurisdictional cooperation. In the Republic of the Philippines, the establishment of FMAs appears to be a good strategy to cope with shifts within national waters, while also addressing other management issues.

Together with resilient fisheries management, the FAO Adaptation Toolbox can be used to support the sector's adaptation to climate change. The institutional adaptation, livelihood adaptation, and risk reduction and management areas of the Toolbox facilitate the identification of different types of adaptation responses within the cycle of adaptation. During the group exercise, the cycle of adaptation and the FAO Toolbox were put into practice and a variety of risks and adaptation approaches were presented and discussed.

Participants also acknowledged the on-going portfolio on climate change adaptation in the Republic of the Philippines and welcomed the offer from FAO to provide BFAR with further technical assistance to build its capacity. This will be done through a workshop on adaptation planning to support regional directors to develop adaptation pathways, and identify priority activities for a climate finance concept note.

To guarantee the sustainability of the sardine fishery in the Republic of the Philippines, FAO proposed to support the implementation of the National Sardines Fisheries Management Plan at the scale of a selected FMA, taking into account measures to cope with the expected impacts of climate change at the FMA scale, and integrating measures to restore and conserve key ecosystems related to essential sardine fish habitats.

1.5 REFERENCES

Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S. & Poulain, F., eds. 2018. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. 628 pp. (also available at http://www.fao.org/3/CA0356EN/ca0356en.pdf).

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ANNEX 1.1 – List of participants

	Last name	First name	M/F	Designation	Office/Agency
1	Makinano	Romeo	M	Division Chief II	PFDA, Bulan Fisht Port
2	Baticados	Didi	F		ISDA Inc
3	Baraocor	Lainie	F	PO II	BFAR
4	Arenas	Ana Mane	F	AA II	BFAR
5	Ephine	Metillo	M	Prof. Dean	MSU-IIT
6	Calvan	Dennis	M	Manager	RARE
7	Mesa	Sheryll	F	NSAP Project Leader	BFAR VI
8	Delos Reyes Jr.	Victorino	M	LGU-Ajuy, PLO	MFARM-C
9	Baltar	Jethro Emmanuel	M	NSAP Assistant Project Leader	BFAR-NSAP5
10	Rrepollo	Charina Lin	F	Senior Leader	UP-MSI
11	Ignacio	Divina	F	NSAP P.L	BFAR IX
12	Naguit	Maria Rio	F	UPRDE	JRMSU
13	Lim	Edgar	M	MOR	PERMEX
14	Baylosis	Roberto	M	EU President SoPhil	SOPHIL
15	Torres	Francisco Jr.	N	NSAP Coordinator	NFRDI
16	Flores	Nicko Amor	M	NSHRRA	NFRDI
17	Punongbayan	Andalus	F	Research Assistant	MSI
18	Valerio	Roberto G	M	Executive Director	IGZI
19	Villaroy	Cesar	M	Prog	MSI
20	Quillope	Sofia Joy	F	DMD	CCC
21	De Jesus	Diovanie	M	Marine Scientist	OCEANA
22	Geronimo	Rollan	M	Fisheries Modeler	MERF Fish Right
23	Francisco	Benjamin	M		
24	Ramos	Gloria	F	VP	OCEANA
25	Velayo	Isidro Jr.	M	RD	BFAR IX
26	Ramirez	Kristine	F	Development Manager	RARE

	Last name	First name	M/F	Designation	Office/Agency
27	Jalotjot	Hadji	M	University Researcher	UPLB
28	Baltazar	Perca	F	Technical Staff	DASWCCO
29	Masallo	Jorybel	F	Sr. Weather SP	PAGASA
30	Campos	Wilfred	M	Professor	UP Visayas
31	Espana	Norievill	F	Marine Conservation Officer	DENR/ UNDP SMARTSEAS
32	Ramos	Myrna	F	Project Development Officer II	BFAR-CFD
33	Tunacao	Elymi-Ar-J	F	PO IV	BFAR-FPED
34	Roca	Robert	M	Aqua II	BFAR-FRMD
35	Gelma	Maritess	F	AT	LGU-Bulan
36	Porlaje	Rene Zaldy	M	Aqua II	BFAR-FRMD
37	Calzado	Rodolfo Jr.	M	NPO	UNDP-BFAR GMC-PHI
38	Mahinay	Jay-ar	M	PDO II	BFAR-CFD
39	Santos	Mudselleelus	M	Scientist II	UFRDI
40	Zulueta	Jayson Paul	M	Tech Staff	BFAR
41	Quibilan	Miledel	F	Resilience Specialist	FishRight
42	Gamboa	Alexandra	F	Manager of Gort Initiative	RARE
43	Saniano	Marianne	F	Science Campaign Manager	OCEANA
44	Cedo	Kima Karla	F	PDO II	BFAR
45	Mea	Jean	F	Documenter	FAORAP
46	Raquista	Heizel	F	Documenter	FAO
47	Siar	Susana	F	Fishery and Aquaculture Officer	FAO
48	Vasconcellos	Marcelo	M	Fishery Officer	FAO
49	Poulain	Florence	F	Fisheries and Aquaculture Officer	FAO
50	Quilla	Maria Ruzzella	F	Project Development Coordination Specialist	FAO
51	Labaria	Elirozz Carlie	F	CCA-DRR Specialist	FAO
52	Caparas	Paulo	M	GIS Specialist	FAO
53	Bohol	Thea	F	Gender Specialist	FAO
54	Fernandez de La Reguera	Diana	F	Climate Change Consultant	FAO

ANNEX 1.2 – Programme of activities

DAY ONE | 18 SEPTEMBER 2019

08.30–09.00	Registration	
09.00–09.20	Opening remarks	Dir Remia Aparri *BFAR Region VI* Ms Ruzzella Quilla *FAO Philippines*
09.20–09.30	Participants' introduction	
09.30–09.45	NAP-Ag Philippines: background, fisheries in country national climate change policy	Ms Carlie Labaria *FAO Philippines*
09.45–10.10	Introduction to workshop objectives in the context of climate change adaptation planning (with a focus on impact and vulnerability assessment)	Ms Florence Poulain *FAO NFI*
10.10–10.30	Coffee break	
10.30–11.00	Climate stressors in the Philippines (relevant to sardines dependent coastal communities)	Ms Jorybell Masallo *DOST-PAGASA*
11.00–11.50	Projected impacts on fisheries habitat	Mr Rollan Geronimo *USAID Fish Right*
11.50–12.10	Projected climate change impacts on global catches and on Philippines sardines fisheries Discussions on drivers and projected impacts	Ms Diana Fernandez *FAO NFI*
12.10–12.25	Q&A	
12.30–13.30	Lunch	
13.30–14.30	Brief description of the Philippines sardine fisheries, their socio-economic importance and climate/non climate stressors	Dr Wilfredo Campos *UP Visayas* Ms Didi Baticados *ISDA, Inc.*
14.30–15.00	National Stock Assessment Programme	Mr Francisco Torres *NFRDI*
15.00–15.30	Coffee break	
15.30–16.00	Vulnerable groups : Gender and climate change	Ms Susana Siar *FAO RAP*
16.00–16.30	Wrap up discussions: Agree main risk/vulnerability factors to sardine fisheries and related livelihoods	Mr Marcello Vasconcellos *FAO NFI*

16.00–16.30	**Discuss possible implications for other species and areas**	Mr Marcello Vasconcellos *FAO NFI*

DAY TWO | 19 SEPTEMBER 2019

09.00–10.00	**Recap of the main findings of Day 1** **Potential responses: Management implications**	Mr Marcello Vasconcellos *FAO NFI*
10.00–10.40	**BFAR CFD – National Sardines Management Framework Plan**	Ms Kima Karla Cedo *BFAR*
	Additional Information	Regional directors 5,6,9
10.40–11.00	**Discussions / Reactions** • Private Sector • Local Government Units • NGOs / CSOs	
11.00–11.10	Coffee break	
11.10–12.10	**Fisheries vulnerability assessment of sardine sector in the Philippines (FishVool) / Expanded Vulnerability Suitability Analysis (EVSA)**	Dr Mudjekeewis Santos *NFRDI*
	BFAR CC-DRRM Action Plan	Ms Lainie Baraocor *BFAR*
12.10–12.30	**Addressing Sardine Catch Wastage**	Mr Benjamin Francisco *Bulan Fish Port*
12.30–13.20	Lunch	
13.20–14.10	**Example of gender sensitive value chain analysis for seaweeds to illustrate types of adaptation recommended in the Toolbox**	Ms Thea Bohol *FAO Philippines*
14.10–14.40	**Potential responses: FAO Adaptation Toolbox**	Ms Florence Poulain *FAO NFI*

14.40-16.30
(incl. coffee break)
	WORKSHOP
	• Mapping Exercise
	• Adaptation Planning
	  • What responses
	  • Where
	  • Target groups
	  • Who (BFAR, DENR, FAO, USAID, UNDP, Rare)
		FAO

16.30-16.40	**Concluding remarks**	Ms Carlie Labaria *FAO Philippines* Dir Isidro Velayo Jr., MDM *BFAR Region IX*

Chapter 2

A baseline report on the current status of the sardine fishery in the Republic of the Philippines

Wilfredo L. Campos and Alexanra Bagarinao-Regalado

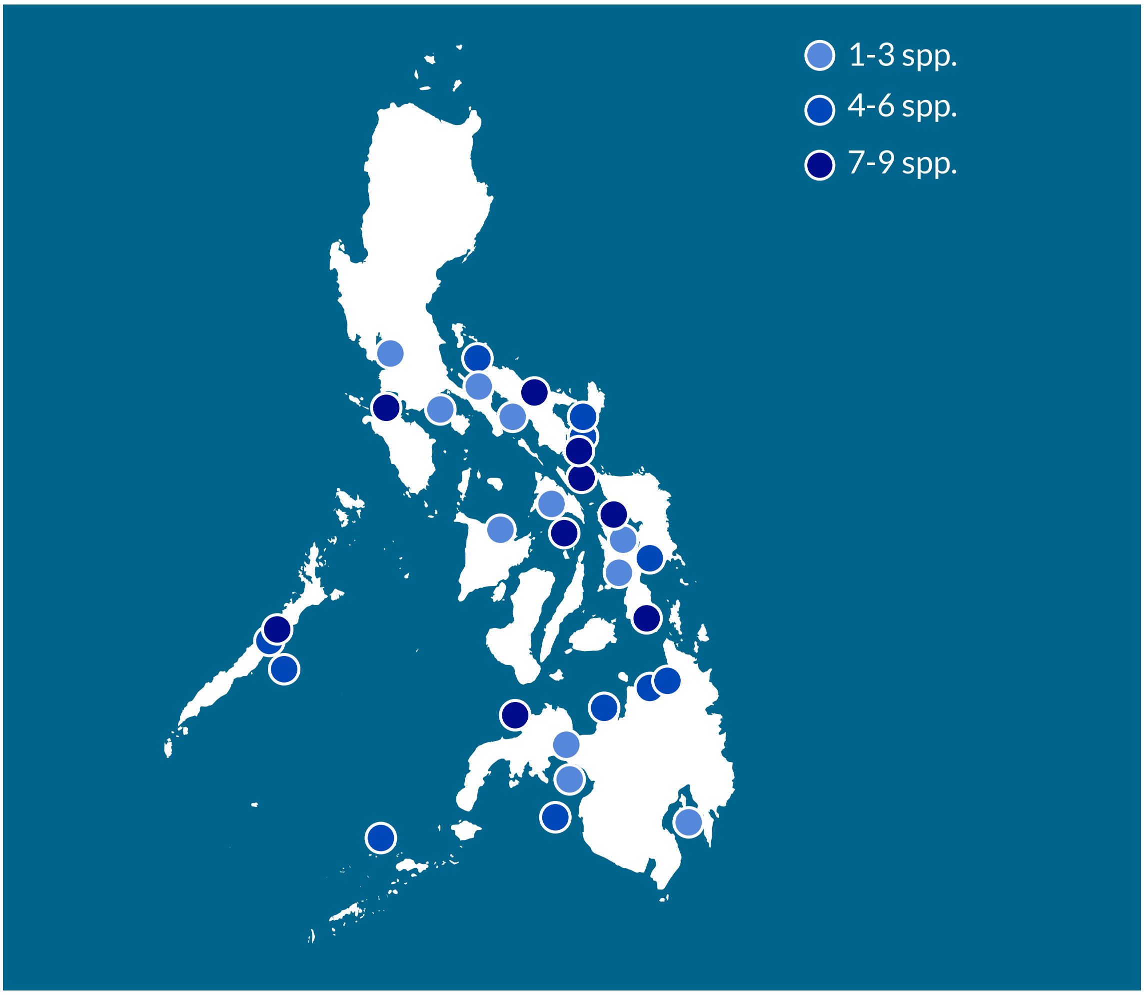
2.1 OVERVIEW OF THE SARDINE FISHERY AND RESOURCES EXPLOITED IN THE REPUBLIC OF THE PHILIPPINES

2.1.1 CLUPEID SPECIES IN THE REPUBLIC OF THE PHILIPPINES

Clupeid (sardine and herring) diversity is highest in the Indo-West Pacific region, the proposed geographic origin of this family (Lavoue *et al.*, 2012). In the Western Central Pacific, there are 37 species of clupeids present and 14 of these species, belonging to six genera, are distributed in the waters of the Republic of the Philippines (FAO, 1999). These include:

1. *Amblygaster sirm*
2. *Dussumieria acuta*, *Dussumieria elopsoides*
3. *Escualosa thoracata*
4. *Herklotsichthys dispilonotus*, *Herklotsichthys quadrimaculatus*
5. *Sardinella albella*, *Sardinella fimbriata*, *Sardinella gibbosa*, *Sardinella lemuru*, *Sardinella hualiensis*
6. *Spratelloides delicatulus*, *Spratelloides gracilis*.

FIGURE 2.1
The diversity of clupeid species for 30 fishing grounds reviewed in the Republic of the Philippines



Source: Map adapted from Bagarinao and Campos, 2018a.

Not included in this list are *Sardinella tawilis*, the only freshwater sardine in the world endemic to Taal Lake in the Republic of the Philippines (Quilang *et al.*, 2011); the newly reported sardine species *Sardinella goni* (Stern, Rinkevich and Goren, 2016); and *Sardinella pacifica* (Hata and Motomura, 2019), which is believed to be the true identity of the local *Sardinella fimbriata*. Cryptic diversity within *Sardinella gibbosa* has also been reported (Thomas *et al.*, 2014). Figure 2.1 shows the diversity of clupeids in the various fishing grounds of the Republic of the Philippines.

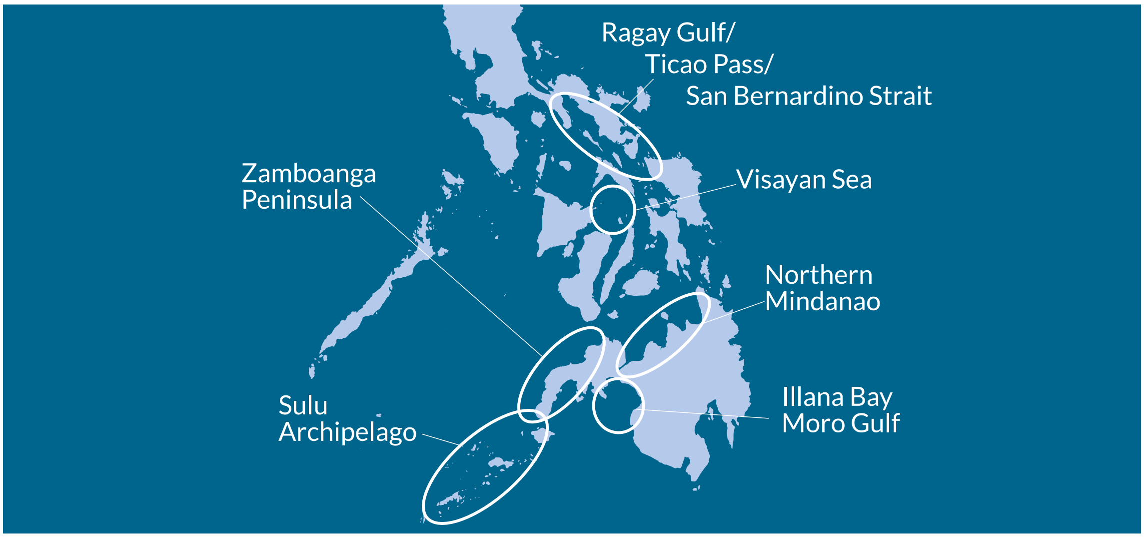
Although Philippine sardines are exceptionally diverse (a total of 17 species), there are inconsistencies in their identification, as shown in the published literature (Seale, 1908; Herre, 1953; Whitehead, 1985; Conlu, 1986; Quilang *et al.*, 2011). A recent review of resource assessments conducted in different areas across the country (Campos *et al.*, 2017) reported changes in the dominant sardine species in several fishing grounds. Unfortunately, shifts in species composition can no longer be verified and remain ambiguous because of historically incorrect species identification. Such shifts in the abundant sardine species may require different strategies to ensure that fisheries are sustainable.

2.1.2 AREAS FISHED AND FISHING GEAR USED

All species belonging to the *Amblygaster*, *Escualosa* and *Sardinella* genera are targeted and exploited in the country (FAO, 1999; Willette *et al.*, 2011). Based on available information, there appear to be six major fishing grounds where sardines make up a substantial portion (>30 percent) of the fishery (Campos *et al.*, 2017). These include (Figure 2.2):

1. Ragay Gulf/Ticao Pass/San Bernardino Strait
2. Visayan Sea
3. Northern Mindanao – Butuan Bay and west to Iligan Bay
4. Zamboanga Peninsula
5. Illana Bay to Moro Gulf
6. Sulu Archipelago.

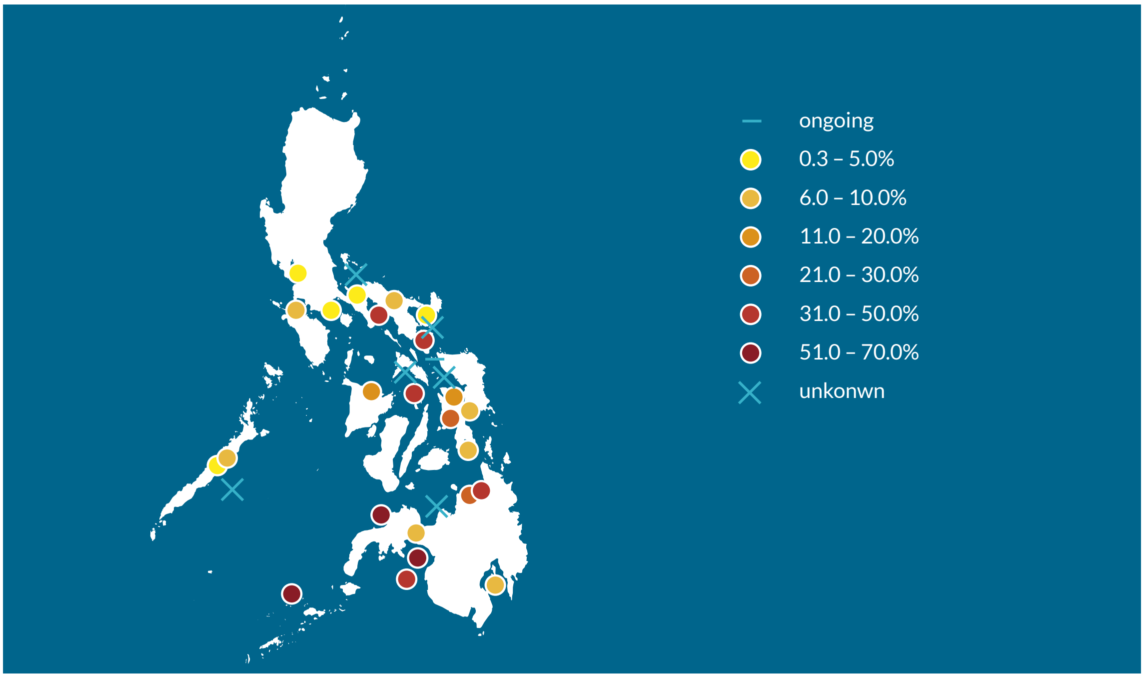
FIGURE 2.2
The six major fishing grounds in the Philippines where sardines make up a substantial part (>30 percent) of the fishery



Source: Campos *et al.*, 2017.

No information is available for Tanon Strait. Similarly, insufficient information is available for the Verde Island Passage, in spite of the substantial fishery for “dulong”, which consists predominantly of early juvenile clupeids (Campos, Nabuab and Malingin, 2011). Figure 2.3 shows the relative contribution of clupeids to total annual landings in various fishing grounds in the country. Sardines occupy the pelagic domain, particularly the uppermost layer of the ocean (approximately 0 m to 200 m) (Fréon et al., 2005). The pelagic habitat can be distinguished by the nature of water masses (i.e. temperature, salinity, current direction, upwelling system, plankton populations, seasonality of production, etc.). The majority of sardines are strongly migratory and inhabit areas of high productivity, thriving in upwelling regions (Checkley et al., 2009). They dominate these areas because of their feeding behaviour, feeding abundantly on microplankton using a filter or particulate feeding mode, depending on what is the most appropriate in a particular food environment. This makes them highly opportunistic and efficient foragers, occupying a key position in marine ecosystems.

FIGURE 2.3
The relative contribution of clupeids to total annual landings for 30 fishing grounds eviewed in the Philippines



Source: Map adapted from Bagarinao and Campos, 2018a.

The six major fishing grounds identified above are among the most highly productive sardine-supporting habitats in the country. Ragay Gulf/Ticao Pass/San Bernardino Strait are deeper basins (approximately 100 m to 300 m depth) bordering the shallow Visayan Sea. Oceanic water from the Pacific enters through San Bernardino Strait, then flows west to Ticao Pass. Hence, high primary production in these areas may be related to the convergence of water masses (fronts) entering through San Bernardino Strait from the Pacific Ocean, and internal water masses in the vicinity of Ticao Pass and northwest Samar, and how these vary with the seasons. These fronts are dependent on the currents and their location and intensity.

The Visayan Sea is very shallow with depths ranging from 6 m to 96 m, making it very productive. High primary production in this area is attributed largely to mobilized nutrients from land through several river systems in areas bordering it. In Bohol sea (Butuan Bay and west to Iligan Bay), primary production is fuelled mainly by nutrients it receives from the Agusan River, the second largest river in the Republic of the Philippines and possible entrainment of subsurface water through "double estuarine circulation" (Villanoy *et al.*, 2011). In Moro Gulf, sardines are mainly distributed in coastal areas within the bays (Illana Bay and Sibuguey Bay) into which several river systems drain. The gulf is also one of the country's main tuna fishing grounds.

Along the northern coast of Zamboanga Peninsula, high primary production is driven by upwelling in which intensity and duration are highly influenced by the El Niño–Southern Oscillation (ENSO). The coast is oriented northeast to southwest, consistent with the axis of the monsoon winds. When the northeast monsoon wind blows over the surface of the water, conditions become favourable for offshore Ekman[1] transport, displacing inshore surface waters with cold, nutrient-rich waters from below (Villanoy *et al.*, 2011). Biological blooms in Sulu Archipelago are driven by interval wave and water mass mixing (Lermusiaux *et al.*, 2011).

Small pelagic fisheries make up over half of the total marine capture fisheries' production of the Republic of the Philippines. Of this, sardines make up the bulk of the catch. A wide range of fishing gears is used to target sardines; a list of these fishing gears is presented in Table 2.1 for the six major sardine fishing grounds identified. The list is limited to gears reported in the studies reviewed and therefore may not be complete.

TABLE 2.1
List of fishing grounds with corresponding major landing ports and fishing gears used to target sardines

Fishing grounds	Fishing/landing ports	Fishing gears targeting sardines*
1. Ragay Gulf/Ticao Pass/ San Bernardino Strait	Pasacao, Camarines Sur Monreal, Ticao Island Bulan, Sorsogon	BT, BN, BS, BSGN, DS, DGN, EGN, FN, FC, LN, MHL, PS, RN, Scoop N w/ Dyn, Stationary LN, SGN, Trammel N
2. Visayan Sea	Northern Iloilo (Concepcion, Estancia, Carles); Masbate (facing Asid Gulf, adjacent to V Sea; Northern Cebu (Daan-bantayan, Medellin, San Remigio), Bantayan Island, Cebu; Northern Negros Occidental (Cadiz, EB Magalona, Escalante, Sagay)	DGN, BN, BS, Boat S/DS, BSGN, Cast N, DS, Dyn, EGN, FN, FC/Weirs, LN, MWT, MHL, Otter T, PS, RN, RHS, Scoop N, Stationary LN, SGN
3. Northern Mindanao (Bohol Sea – Butuan Bay and west to Iligan Bay)	Agusan del Norte (Tubay, Cabadbaran, Buenavista), Misamis Oriental (Magsaysay, Gingoog, Jasaan, Opol, Naawan), Misamis Occidental (Oroquieta City)	RN, BN, DGN, EGN, Mod DGN, Mod EGN
4. Zamboanga Peninsula (East Sulu Sea)	Zamboanga del Norte (Dapitan, Dipolog, Sindangan), Zamboanga Citya	RN, BN, DGN, EGN, Mod DGN, MHL, Scoop N, PS
5. Illana Bay to Moro Gulf	Pagadian City, Sibugay	RN, BN, PS, DS, MHL, FC
6. Sulu Archipelago	Basilan, Sulu (Jolo, Isabela City), Tawi-Tawi	PS, RN, BN, Scoop N, MHL

*BT (baby trawl), BN (bag net), BSGN (bottom set gillnet), DS (danish seine), DGN (drift gillnet), EGN (encircling gillnet), FN (filter net), FC (fish corral), LN (lift net), MHL (multiple hook and line), PS (purse seine), RN (ring net), Scoop N (scoop net), SGN (surface gillnet), Dyn (dynamite), Trammel N (trammel net), BS (beach seine), Boat S (boat seine), Cast N (cast net), MWT (midwater trawl), Otter T (otter trawl), RHS (round haul seine), Mod (modified).

[1] Ekman transport is part of Ekman motion theory, first investigated in 1902 by Vagn Walfrid Ekman. Winds are the main source of energy for ocean circulation, and Ekman Transport is a component of wind-driven ocean current.

Commercial fishing vessels (including small commercial vessels of between 3 to 20 gross tonnage (GT) typically include purse seine, ring net, bag net, drift gillnet, Danish seine, round haul seine and midwater trawl. Commercial vessels are large (> 3 GT), equipped with high powered engines, and carry crews of between 7 and 20 people. These vessels are supposed to operate beyond the municipal waters (15 km) however, some still operate closer to the coast. Most target large juvenile and adult sardines using nets with larger mesh sizes. However, boat seines and bag nets use finer meshed nets (< 1 cm) to catch large amounts of small and early juvenile sardines, as well as anchovies and other early juvenile fish referred to locally as "*dulong*", "*lobo-lobo*" (Visayas) and "*sihag-sihag*" (Mindanao).

Municipal fishing vessels are relatively small boats of less than 3 GT, typically manned by one to four fishers and operating in coastal waters within the 15 km zone because of the size and power limits of their vessels. These gears generally include:

- encircling gillnets;
- drift gillnets;
- surface gillnets;
- lift nets;
- baby and otter trawls;
- hook and lines;
- trammel nets;
- boat seine;
- beach seine;
- fish corral and weirs; and
- cast net and scoop nets.

FIGURE 2.4

Map showing the location of fishing operations of vessels from Roxas City and along the Visayan Sea coast of Masbate, where sardines are regularly caught, based on the results of fisheries profiles through focused group discussion (FGD)

Red symbols (fishing gears that catch adult sardines); green symbols (fishing gears that catch early juvenile sardines)

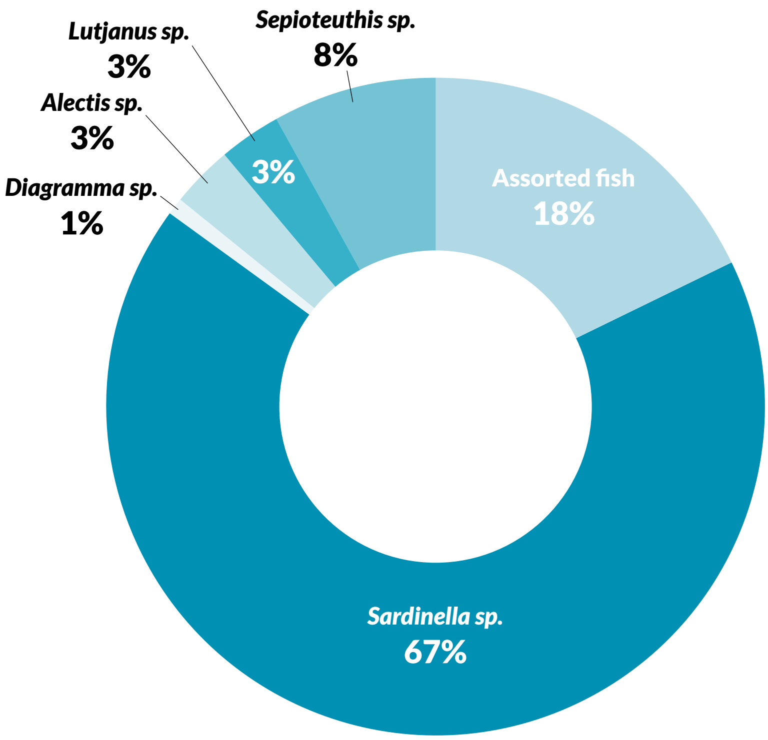
Source: adapted from Campos, Bagarinao and Nunez, 2019.

Fishing gears that catch early juveniles use fine mesh nets and typically operate in nearshore coastal waters (Figure 2.4, Visayan Sea). These include:

- beach seine;
- lift nets;
- filter nets;
- fish corral;
- boat seine;
- cast nets;
- bag nets;
- scoop nets; and
- tidal weirs.

In Verde Island Passage, early juveniles are locally known as "dulong" and are caught mainly by scoop nets. Encircling gillnets, small drift gillnets and surface gillnets catch large juveniles and adult sardines and comprise the bulk of the catches from municipal waters. Both commercial and municipal fishing vessels use accessory devices to increase fishing efficiency and enhance their catches, such as fish finders, high-powered lamps (super lights), fish aggregating devices (FADs) and hookah compressors (to close nets underwater). Some even use dynamite. Fisheries are typically multispecies, meaning that species occurring at the same time are caught by the same gear type. Commercial vessels targeting sardines usually do not target other species. Municipal fishers shift gear types depending on sea conditions (related to monsoons), seasons (lean versus peak months) and other circumstances such as closed seasons.

FIGURE 2.5
Catch composition of encircling gillnets in Concepcion, Iloilo



Source: Campos *et al.*, 2014a.

Although some municipal fishing gears target sardines and other small pelagics such as *Rastrelliger* spp., *Selar* spp. and *Decapterus* spp., they also capture other species such as squid and reef-associated fish, as shown in the catches of encircling gillnets from western Visayan Sea (Figure 2.5). Interactions between small pelagic fisheries and fisheries for large pelagics are limited to catches of juvenile tuna, especially around FADs. Adult and mature tuna are caught by longlines further offshore.

The annual fisheries profiles published by the Bureau of Fisheries and Aquatic Resources (BFAR) show counts of all commercial fishing vessels by size categories (small: 3 GT to 20 GT; medium: > 20 GT and large: > 150 GT) but the breakdown by gear type and target resource is not available. A national inventory and registration of fishing gear and vessels (BoatR) and fishers (FishR) in the municipal sector was initiated by BFAR and implemented by local government units (LGUs) in 2014 and is supposedly updated annually. The available data so far provides numbers but not by gear type. There has been no evaluation of compliance rates for this effort.

TABLE 2.2
Estimated annual catch (tonnes) of major gear types targeting sardines in the Visayan Sea

Monitored site/ Province	Municipal			Commercial			
	DNG	EGN	Mdw T	DGN	EGN	Mdw T	RN
Concepcion, Iloilo					*620.4*		*93.6*
Carles, Iloilo					*522.5*		
Iloilo (rest)	756.7	569.5			277.1		
Cadiz, Negros Occ.					*127.6*		
Negros Occ. (rest)	642.3	483.3		30.7	260.8	108.3	
Roxas City					940.6	176.8	499.0
Bantayan, Cebu		*174.9*					
Cebu (rest)	2 974.0	374.7		184.5	120.4		
Baldud, Masbate	475.2	*26.7*					
Milagros, Masbate		295.2	57.4	*948.4*			
Cawayan, masbate	219.7	177.9	18.0				
Placer, Masbate	*152.6*	58.8	243.7				
Esperanza, Masbate	37.8	558.0					
Sub-total	**5 258.2**	**2 719.0**	**319.1**	**1 163.7**	**2 869.3**	**285.1**	**592.5**
% of the total catch			**62.8**				**37.2**
Total ann catch (mt)							**13 207.0**

(DGN = drift gillnet; EGN = encircling gillnet; Mdw T = midwater trawl; RN = ring net).
All italicized values are based on actual catch and effort monitoring from February to December 2018, except in Carles and Concepcion, Iloilo, which were covered from October 2017. All other values are extrapolations using information from the fisheries profiles (App. 1–7). All annual estimates cover the period January to December 2018, except for Carles and Concepcion, Iloilo, which cover the period December 2017 to November 2018.

Source: adapted from Campos, Bagarinao and Nunez, 2019.

Information on the relative contribution of various fishing gears to sardine catches is limited to certain areas and basins and some needs to be updated. Table 2.2 shows estimates of annual (January to December 2018) catches from the major gear types (encircling and drift gillnets, midwater trawls and ring nets) targeting sardines in the Visayan Sea, taken from the report of Campos *et al.* (2019).

TABLE 2.3
Summary of gear types and units in the Visayan Sea that target sardines

Fishing gear	Iloilo	Negros Occ	Cebu	Roxas	Bauld	Milagros	Cawayan	Placer	Esperanza	Bantayan
Municipal										
Hook and line		3	16							
Multiple hook and line	225		167	172	208	173		67	275	
Gillnet fixed to FAD	49	14		130	11	0				
Fish corral	17	15				11	10	28	12	
Encircling gill net	103	115	100			41	15	28	31	48
Drifting gillnet	86	73	338		32	31	55	21	21	24
Bottom set gillnet	128	131	358							
Baby trawl		74								
Modified gillnet	1									
Modified castnet (+w/light)	1					593				
Liftnet	14					7			11	
Hanger			22							22
Midwater trawl				31		36	25	174		
Beach seine				23	25	26	44	19	19	
Tidal weir				59						
Small boat seine 1					279	48			34	
Danish seine					4		22	49		
Small boat seine 2						10				
Encircling gill net for shrimp						43				
Filter net						44				
Compressor (dynamite)							23	92	5	
Surface set gill net for anchovies								20	57	
Bagnet								24		
Commercial										
Drift gillnet		1	6							
Encircling gill net (small-scale commercial)	96	26	12	32						
Hulbot (small-scale commercial gear)		10								
Roundhaul seine (small-scale commercial)	15									
Midwater trawl (commercial)		19								
Super hulbot (small-scale commercial)		2								
Sapyaw (small-scale commercial)			12							
Ring net	6			4			?			

Estimates were based on actual catch and effort monitoring, information from the initial fisheries profiling and from research conducted by Ferrer *et al*., (2017) in 18 municipalities bordering the Visayan Sea. The number of fishing gear units by province (Iloilo, Negros Occ. and Cebu) and municipality in Masbate are summarized in Table 2.3. Annual sardine production in the Visayan Sea from January to December 2018, is estimated at 13 207 tonnes. If encircling gillnet catches from Roxas City are excluded (Sibuyan Sea area) the annual production amounts to 12 266.4 tonnes. The contribution of municipal fishing gears to total catch is 62.8 percent while 37.2 percent are catches from commercial (including small commercial) fishing gears (Campos, Bagarinao and Nunez, 2019). The estimated annual sardine catch for the Visayan Sea is only 55 percent of the estimated mean annual sardine production for west Visayas (22 800 tonnes) based on official fisheries statistics from 2002 to 2014 (BAS, 2021). This rather large discrepancy may mean that:

- sardine abundance was particularly low in the Visayan Sea in 2018, which is consistent with the observed very low relative fishing effort at the time;
- the estimate failed to include substantial contributions from other gear types, even if estimates derived from the initial fisheries profiles may themselves already be overestimates; or
- national statistics overestimate actual production (Campos, Bagarinao and Nunez, 2019).

TABLE 2.4
Estimated annual catch (tonnes) of major gear types targeting sardines in the Sulu Sea and Moro Gulf (including Illana Bay) covering the period 1990–2001

Fishing gear	Est. Annual catch (mt) 1999	Est. Annual catch (mt) 2000	Est. Annual catch (mt) 2001	Mean Est. Annual catch (mt)	sd	% contribution
Commercial						
Ring net	1 995.64	1 670.89	2 177.29	1 947.94	256.55	11.70
Bag net	2 840.93	2 230.85	3 815.09	2 962.29	799.06	17.79
Purse seine	6 367.50	5 380.44	6 746.37	6 164.77	705.17	37.03
Danish seine	480.10	725.85	1 028.11	744.69	274.49	4.47
					subtotal	70.99
Municipal						
Hook & line		1 965.57	1 733.01	1 849.29	164.44	11.11
Multiple hook & line		365.20	331.13	348.17	24.09	2.09
Fish corral		36.76	4.93	20.85	22.51	0.13
Others*		634.36	4 587.78	2 611.07	2 795.49	15.68
					subtotal	29.01
TOTAL	11 684.2	13 009.9	20 423.7	16 649.1		100.0

*spear gun, drift gill net and gill net

Source: BFAR-NSAP region 9 (2002).

Table 2.4 shows estimates of annual catches from the major gear types targeting sardines in the Sulu Sea and Moro Gulf (including Illana Bay) for the period 1999 to 2001 (BFAR-NSAP Region IX, 2002). Estimates are based on actual monitoring but are limited to the southern portion of Zamboanga Del Norte (Sindangan), Zamboanga City, Sibugay and Basilan. Hence, data on municipal fishing gears targeting sardines, such as encircling gillnet and drift gillnet, which are used in substantial numbers in the northern portion of Zamboanga del Norte (Dapitan and Dipolog), are not reflected. The annual sardine production based on monitored catches for the time period ranged from 11 684.2 tonnes to 20 423.7 tonnes, with the majority of the catches contributed by commercial fishing gears (70.99 percent).

Among the commercial fishing gears, purse seines constituted 31.2 percent of the sector and contributed the highest in terms of catch volume, amounting to 6 164.77 tonnes (52.2 percent) from 1999 to 2001 (Table 2.4) and more recently, 22 243.9 tonnes (97.0 percent) in 2013 (BFAR-NSAP Region IX 2002, 2016).

In the area of northern Zamboanga Peninsula (Dapitan Bay to Sindangan Bay) and northern Mindanao (Butuan Bay to Iligan Bay), a mean annual sardine production of 39 496 tonnes was estimated from 2011 to 2014 (De Guzman *et al*., 2015), with landed catches from the Dapitan-Dipolog-Sindangan Bay areas (northern Zamboanga Peninsula) making up the bulk (17 870 tonnes, 45.2 percent). However, these values are underestimates since they appear to cover only those landing sites monitored during the study and are not extrapolated to all landing sites. Table 2.5 shows mean catch rates (kg/fisher/trip) of major fishing gears targeting sardines during the same period. Unfortunately, the number of fishing gear units and fishing frequency were not included in the report, so the relative contribution by gear could not be extrapolated.

TABLE 2.5

Catch rates (kg/fisher/trip) of major fishing gears targeting sardines in northern Zamboanga Peninsula (Dapitan to Sindangan Bay) and northern Mindanao (Butuan to Iligan Bay)

Fishing gears	Catch rates (kg/fisher/trip)				
	Dapitan-Dipolog-Sindangan Bay	Iligan Bay	Macajalar Bay	Butuan Bay	Gingoog Bay
Commercial fishing gears					
Bag net	33.72	-	108.72		
Ring net	54.16	17.76	79.37		
Municipal fishing gears					
Bag net (small)	27.32	35.58			
Beach seine	14.48	8.09		0.33	0.2
Bottom set gill net	15.75	8.75	15		
Drift gill net	19.67	30.37	9.93	46.92	39.45
Encircling gill net	43.74	12.32	52.56	22.24	
Scoop net	137.19	39.6		75.81	262.32

Source: BFAR-NSAP Region IX, 2002.

For the Sulu Archipelago, catch monitoring in 2018 showed that annual sardine production amounted to 4 323.05 tonnes (Table 2.6), with the majority of the catches contributed by municipal fishing gears (75.02 percent). Among these, drift gillnets contributed the highest in terms of catch volume (1 956.78 tonnes, 45.26 percent).

TABLE 2.6
Estimated annual catch (tonnes) of major gear types targeting sardines in the Sulu Archipelago (Basilan, Sulu and Tawi-Tawi) for the year 2008

Fishing gear	No. of gear units 2009	Est. annual catch (tonnes) 2008	Contribution to catches (%) (2008)	Contribution to catches by sector (%) 1998–2008
Commercial				
Ring net	140	1 000.0*	23.13	79.0
Bag net	104	80.0*	1.85	21.0
subtotal	244	1 080.0*	24.98	
Municipal				
Drift gillnet	150	1 956.78	45.26	58.0
Multiple hook & line	5 232	556.78	12.88	13.0
Gillnet	1 827	510.57	11.81	11.0
Hook and line	11 338	218.92	5.06	6.0
Others				12.0
subtotal	18 547	3 243.05	75.02	
TOTAL	18 791	4 323.05	100.0	

*approximate value based on bar graph presented in the report
Source: adapted from Mamalangkap, Mokamad and Ayub, 2011.

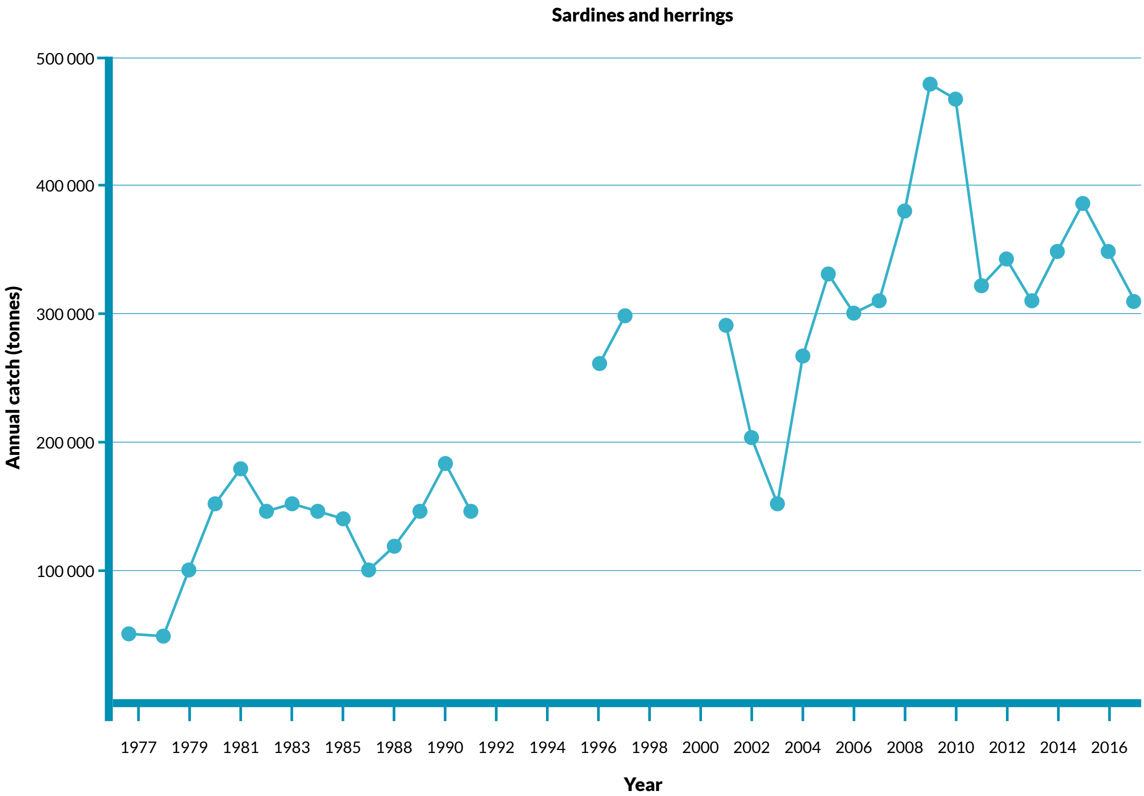
2.1.3 AVAILABLE KNOWLEDGE ON THE STATUS OF FISHERIES RESOURCES

Sardine fisheries production

Annual sardine and herring production in the country from 1977 to 2017 is shown in Figure 2.6. From 1977 to 1987, estimates were based on the BFAR landing site monitoring programme, following international protocols. However, the mandate to gather fisheries production data nationwide was transferred to another agency, so estimates from 1988 to the present are based on a different but unknown monitoring scheme undertaken by the Bureau of Agricultural Statistics (BAS) and more recently, the Philippine Statistics Authority (PSA). Because details of the latter monitoring scheme remain unknown, the reliability of estimates are questionable. Unfortunately, these are the only available national fisheries statistics. Assuming that any under- or over-estimation is similar from year to year (after 1987), the relative trend shows a decrease from 2009. This may not necessarily reflect the trend in the various fishing grounds.

Current fisheries statistics do not provide total catch by fishing ground. For the earlier period from 1977 to 1995, estimates of "annual catch" for each fishing ground are available, but the data for the years 1988 to 1992 refer only to commercial catches because of the transition in the monitoring agency mentioned above. From 1995 to the present, annual catch estimates from the BAS are presented by region only, and no longer by fishing ground. The National Fisheries Research and Development Institute (NFRDI) initiated the National Stock Assessment Programme (NSAP) through the BFAR regional offices to monitor landings in selected fishing grounds in the country in 1998. The NSAP estimates, however, refer only to monitored landings at selected landing sites. While these may cover commercial catches adequately, they underestimate municipal catches which may make a substantial contribution to total sardine catches in certain fishing grounds (discussed further below). Hence the incompatibility and discrepancy between annual catch estimates from BAS and BFAR-NSAP are results of different sampling methods and efforts (Willette *et al.*, 2011). The lack of consensus in monitoring schemes and absence of cooperation in the verification of fisheries statistics results in continued low confidence in annual catch estimates reported for the Republic of the Philippines.

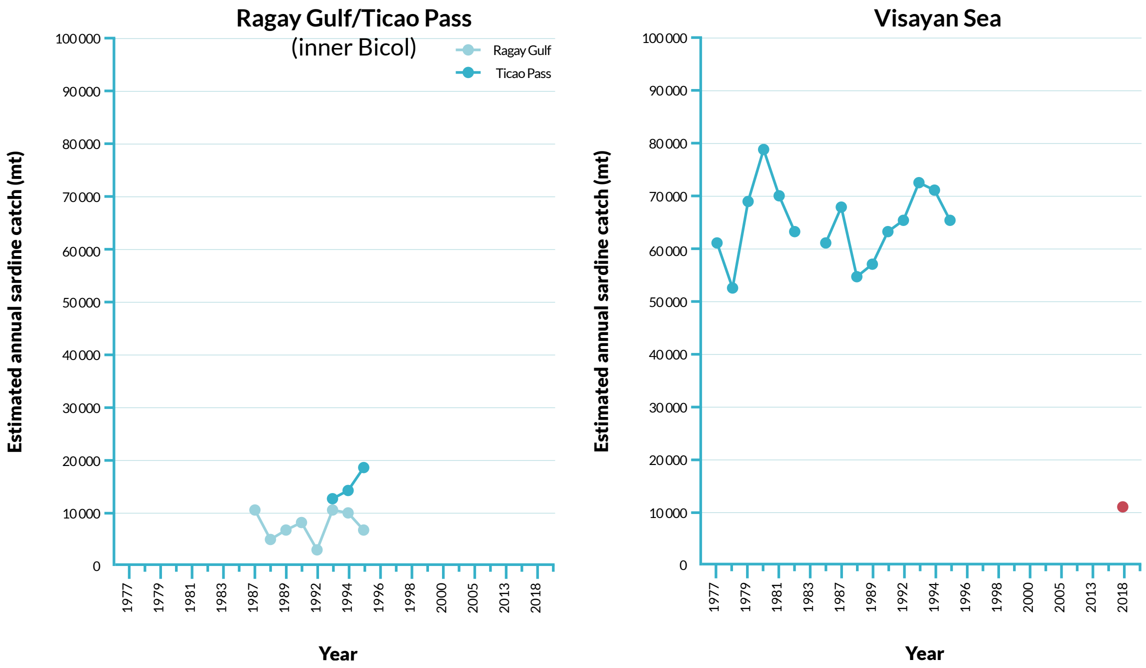
FIGURE 2.6
Total annual sardine and herring production in the country from 1977 to 2017



Source: PSA.

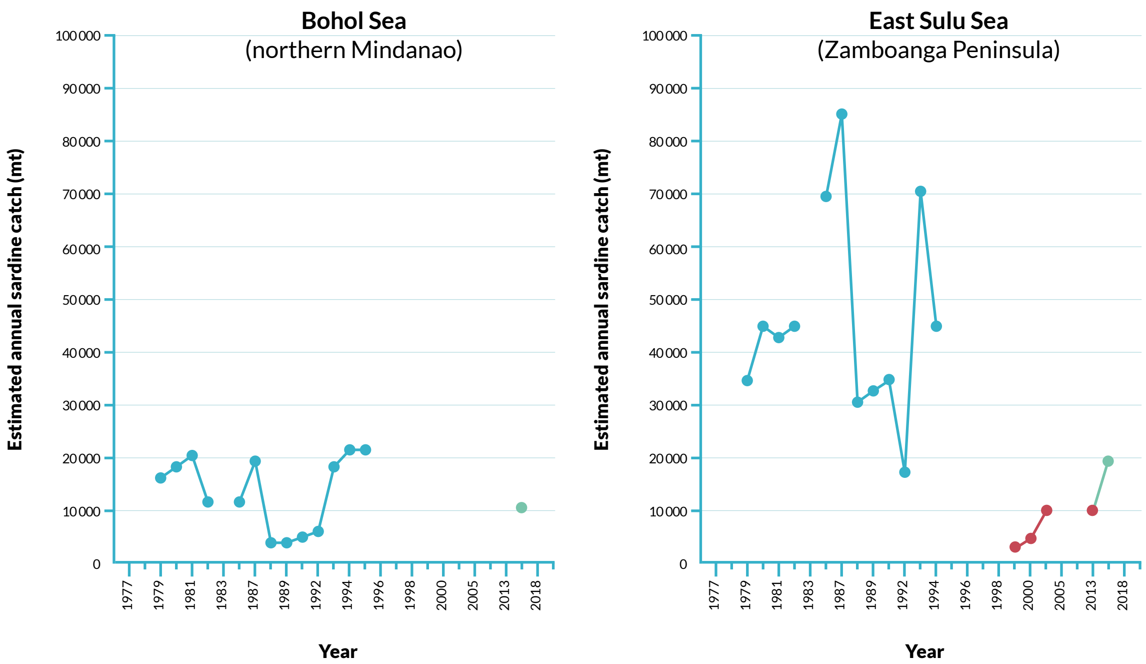
Figure 2.3 provides estimates of the contribution of clupeids to annual total landings for 30 fishing grounds around the country. Figures 2.7 to 2.9 show the estimated annual sardine catch for the six major fishing grounds identified (Figure 2.2). Using the available data on annual catch (all species) for each fishing ground (1977 to 1995; BFAR), annual sardine catch was estimated using the corresponding percent contribution of clupeids to overall catch for each fishing ground provided in the report of Campos *et al.* (2017). More recent estimates were taken from BFAR-NSAP reports. An overall decreasing trend is common in all fishing grounds, except in the Bohol Sea (northern Mindanao) which includes several bays (Butuan, Gingoog, Macalajar, Iligan and Panguil Bays). The more recent estimates (2000 to the present), however, may not reflect total annual catch from both municipal and commercial sectors adequately because these were based only on monitored catches in major landing centres.

Figure 2.7
Estimated annual sardine catch for Ragay Gulf/Ticao Pass and Visayan Sea based on BFAR Philippine Fisheries profile (1977–1995)



Source: Data for 2018 (red dot) were taken from the report of Campos, Bagarinao and Nunez, 2019.

Figure 2.8
Estimated annual sardine catch for Bohol Sea and East Sulu Sea based on BFAR Philippine Fisheries profile (1977–1995)



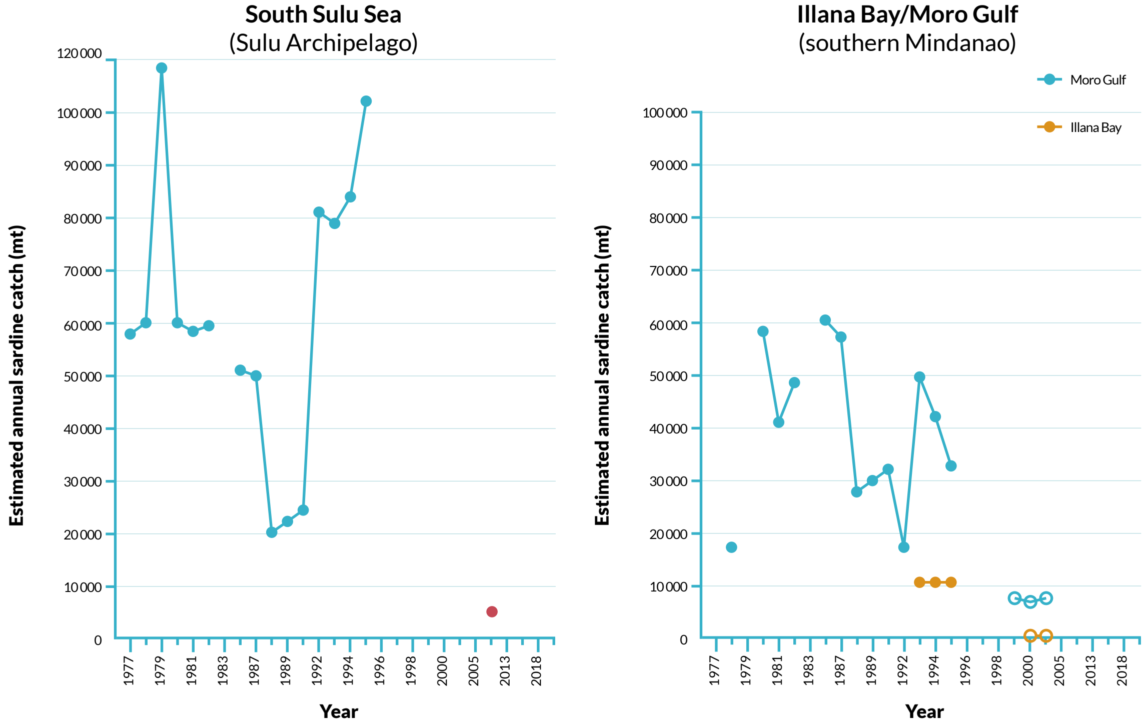
Source: Data from 1999–2001 (red dots) were taken from the report of BFAR-NSAP IX (2002) and data for 2015 (green dot) were taken from the report of de Guzman *et al.* (2015).

There appear to be three species that substantially make up the local stocks of sardines (Figure 2.10). These are *Sardinella lemuru* (includes all records previously identified as *Sardinella longiceps*), *Sardinella gibbosa* and *Amblygaster sirm*. *Herklotsichthys quadrimaculatus* and *Sardinella fimbriata* are also commonly caught, although the former may be more limited to inshore areas.

Among all the sardines found in the country, *Sardinella lemuru* is the most abundant and commercially important. It has been referred to in the past as *Sardinella longiceps* (Seale, 1908; Ingles and Pauly, 1984; Dalzell *et al*., 1990; PSA, 2021) but was recently corrected by Willette and Santos (2013). While *Sardinella lemuru* is the most widespread, it does not dominate clupeid stocks in all these areas. *Sardinella gibbosa*, for example, dominates catches in the Visayan Sea and is common also in the Moro Gulf area. *Amblygaster sirm* dominates catches in Tawi-Tawi, while *Sardinella albella* is abundant in Illana Bay. *Escualosa thoracata* is locally abundant in Sorsogon Bay. We know little about the variability of this geographical distribution pattern. Distribution and dominance of species is a function of habitat characterized by temperature, salinity, current direction, upwelling system, plankton populations, and seasonality of production, among others.

FIGURE 2.9

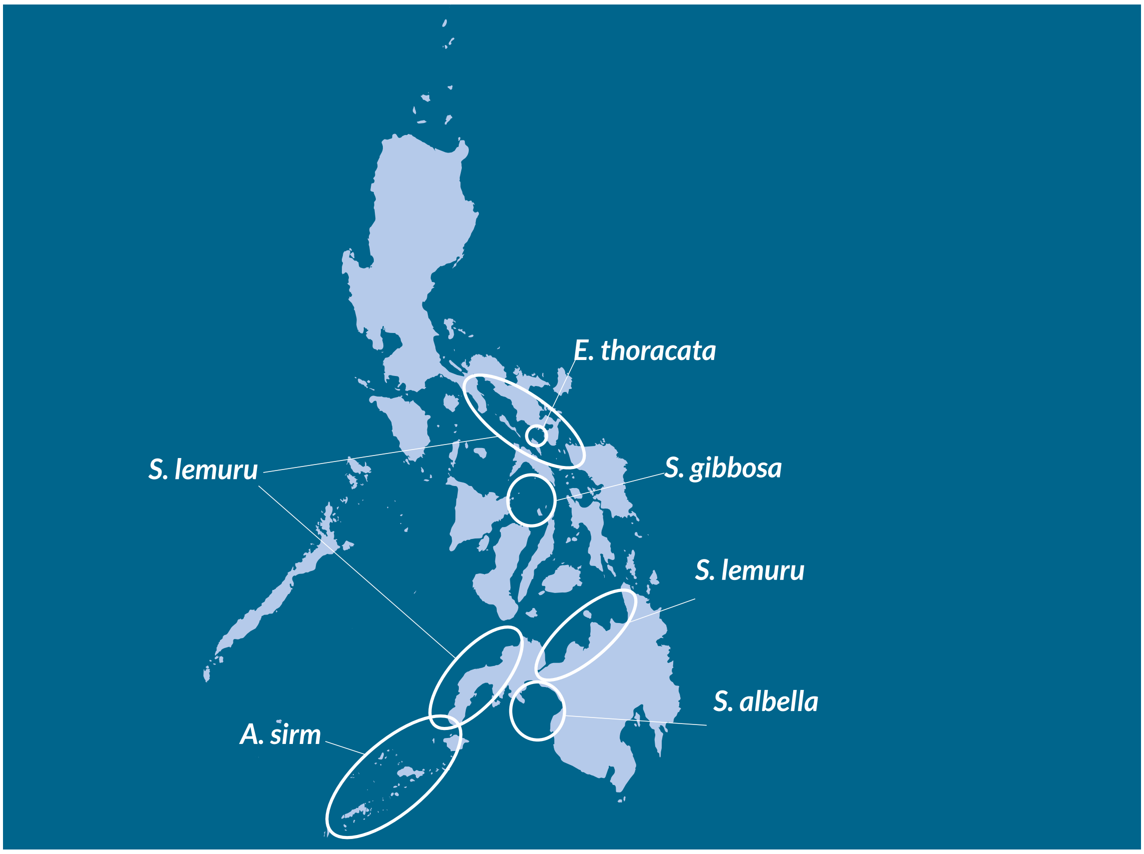
Estimated annual sardine catch for South Sulu Sea and Illana Bay/Moro Gulf based on BFAR Philippine Fisheries profile (1977–1995)



Source: Data on 2008 (red dot) were taken from the report of Mamalangkap *et al.* (2011) but limited only to catches of monitored gears. Data from 1999–2001 (unfilled dots) were taken from the report of BFAR-NASP IX (2002).

In spite of the economic importance of sardines in the Republic of the Philippines, information on sardine biology is limited, poorly understood (Zaragoza, Pagdilao and Moreno, 2004). Updated information on some aspects of the biology is limited to *Sardinella lemuru* and *Sardinella gibbosa* (the two most dominant and widespread species) and as a result, only these species will be discussed briefly here.

FIGURE 2.10
Map showing the major fishing grounds and the major stocks of species that make up the bulk of the sardine fisheries in the Republic of the Philippines



Source: Campos *et al*., 2017.

Sardinella lemuru

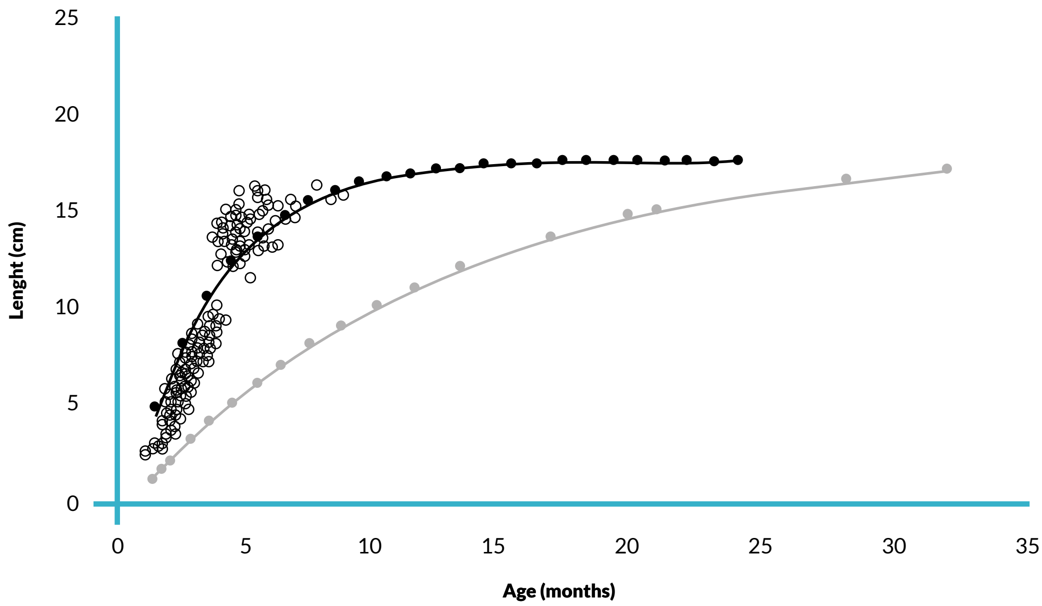
Sagittal otoliths of 144 juvenile from Northern Zamboanga Peninsula (NZP) and 87 mature individuals from NZP and inner Bicol were examined to determine the ages of *Sardinella lemuru*. The sizes of the juvenile specimens analysed ranged from 2.3 cm to 10 cm standard length (SL) corresponding to ages of 34 to 124 days (Bagarinao and Campos, 2017). The size range of processed mature specimens from Inner Bicol was 12.2 cm to 16.2 cm (SL), corresponding to ages of about 137 to 267 days. Smaller and younger mature sardines are being caught off the Zamboanga Peninsula with sizes ranging from 11.5 cm to 16 cm (SL), corresponding to ages of about 110 to 188 days. These results show that *Sardinella lemuru* mature in less than a year (Bagarinao and Campos, 2018b).

Otolith-based mean growth of *Sardinella lemuru* in the northern Zamboanga Peninsula range from 0.78 mm/day to 0.90 mm/day^{-1} (Bagarinao and Campos 2017) and falls within the upper range of reported growth rates of other tropical Clupeiform species. They mature in less than a year (approximately 5.0 months) contrary to what is known, i.e. that they mature after a year (Bagarinao and Campos, 2018a). This length-at-age (otolith-based) growth model shows much faster growth than length-based Von Bertalanffy growth models (K=1.0 and L_∞=21.21) as shown in Figure 2.11. This large discrepancy may be due to the latter model depicting slow growth or may be due to underestimation of ages, particularly of the larger and adult specimens.

Sardinella lemuru typically spawns from October to January, although there appears to be minor spawning the rest of the year in some places such as southern Zamboanga Peninsula and San Vicente and Northern Samar (Tajonera, 2016). Size-at-maturity of this species appears to differ between the Ragay Gulf/Ticao Pass/San Bernardino Strait and Zamboanga Peninsula fishing grounds. Fish in the latter area mature at a smaller size, and presumably younger age, translating to a 2 cm SL difference in the size-at-first maturity (L_m = 13 in northern Zamboanga, 15 in Bicol) (Campos *et al.*, 2017). For northern Zamboanga, the stock's L_m (13 cm SL = 15.6 cm tail length, TL) is smaller than the range of L_m for the stock of the same species off western Australia (L_m = 15.8 to 17 cm TL), where conditions for growth are considered to be suboptimal (Gauhgan and Mitchell, 2000), and much smaller than L_m estimates for Bali Strait in Indonesia (= 21.4 cm TL) (Wujdi *et al.*, 2013).

FIGURE 2.11

The curves represent the von Bertalanffy growth model for *Sardinella lemuru* based on otolith-based length at age data (black dots, black line) and length-based mean estimates of K and L_∞ (K=1.0 and L∞=21.21) from stocks in various fishing grounds in the country (grey).



Tropical sardines can be characterized as having short lifespans (one to two years on average) and fast growth rates, allowing them to attain maturity and maximum size within a shorter time relative to temperate sardine species (Dalzell and Lewis, 1988; Pauly, 1998). Adult sardines can reach a maximum size of 10 to 20 cm SL (FAO, 1999) but can be mature and start spawning at sizes between 7 cm to 13 cm (Williams and Clarke, 1983; Almaquer, 2016). Fecundity is the number of eggs produced by female fish during a spawning season and is a function of size (Miller and Kendall, 2009). Despite their small size, sardines are highly fecund and can spawn more or less 50 000 eggs during a season (Fréon *et al.*, 2005). Intense fishing may change the longevity, size- and age-at-first maturity and fecundity of many species, thus values are specific for each population and will vary depending on the area (Olsen *et al.*, 2004).

In tropical areas like the Republic of the Philippines, spawning can occur throughout the year but usually peaks in periods corresponding to high levels of primary productivity

(Villanoy *et al.*, 2011; Willette *et al.*, 2011). Fecundity estimates of *Sardinella lemuru* in Philippine waters show a range of about 2 555 eggs to 67 000 eggs per individual female ranging in size (SL) from 10 to 16.7 cm (see Table 2.7). This range is lower than the reported range of fecundity of *Sardinella lemuru* from Indonesian waters, where egg counts range from 25 000 eggs to 90 000 eggs per individual female fish. Reproductive potential (e.g. fecundity and egg quality) is a function of size and other maternal conditions influenced by the dynamics of marine ecosystems (climatic effects, fishing etc.).

Table 2.7
Size and fecundity of *Sardinella lemuru* in Philippine waters and other tropical areas

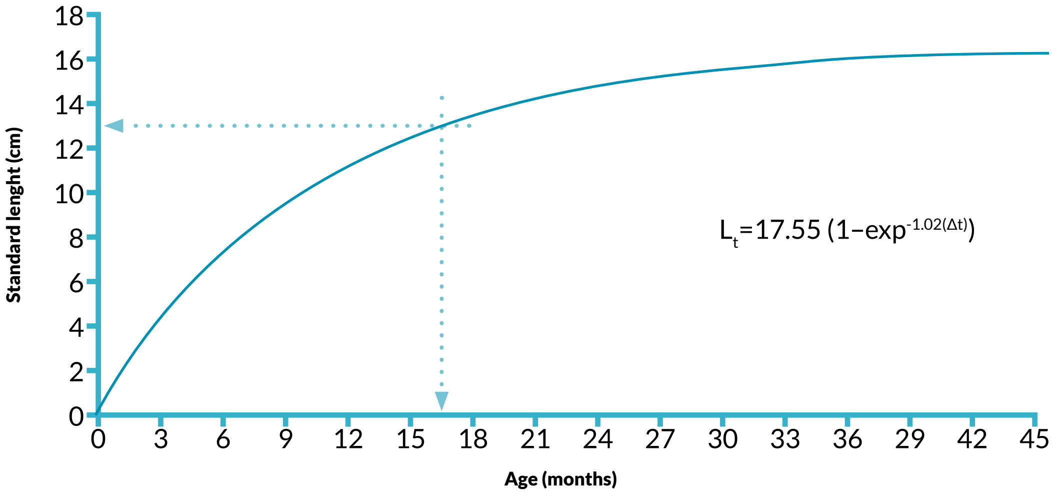
Area	Observed size-at-maturity (cm)	Fecundity	Reference
San Bernardino Strait (inner Bicol) Philippines	13.4–16.7 SL	2 555–56 605	Kwon, 2018
Dipolog-Sindangan Bays Philip-pines	10.0–16.3 SL	11 000–67 000	De Guzman, 2015
Northern Zamboanga Peninsula Philippines	11.5–14.5 SL	6 300–29 250	Paraboles & Almaquer, 2016 (unpublished data)
Western Australia	14.0–15.0 TL	7 248–40 710	Gaughan amd Mitchell, 2000
Bali Strait, Indonesia	~12.8–17.0 TL	25 000–40 000	Merta, 1992
Sibolga Bay, Indonesia	~15.0–24.0 TL	30 000–90 000	Tampubolon, Sukimin and Rahardjo, 2002

Sardinella gibbosa

The length-based growth model of *Sardinella gibbosa* from the Visayan Sea using median growth parameters estimated by Mesa and Guanco (2011) (L_∞ = 20.51cm TL ≈ 17.55cm SL; K = 1.02) is shown in Figure 2.12. Sagittal otoliths were examined to determine the ages of *Sardinella gibbosa*, but the specimens were limited to mature individuals with sizes ranging from 9.3 cm to 11.7 cm SL (mean = 10.4 cm SL [= 12.6cm TL]), corresponding to ages of 92 days to 195 days. The mean age of the specimens was 144 days, or about 4.8 months. Based on the growth model shown (Figure 2.12), the mean size of mature specimens examined would be about 11.3 months relative age, which is more than twice the estimated mean age based on otoliths. Again, a large discrepancy between age-based and length-based growth models has been observed. Continuing work on these species should include the use of scanning electron microscopy, which is more sensitive in defining the fine microstructure in otoliths (Campos *et al.*, 2017).

The timing and the intensity of spawning, and perhaps overall reproductive capacity of *S. gibbosa* are not uniform throughout Philippine waters. Spawning activity reported herein are based on gonado-somatic indices (GSI), distribution of maturity stages, and fecundity data. In northern Mindanao and the Zamboanga Peninsula, typical GSI data shows mean values between 4 percent to 8 percent during peak spawning months (de Guzman *et al.*, 2015). The duration of the spawning season in northern Mindanao seems to shorten from Iligan Bay in the west to Butuan Bay in the east. Spawning in Iligan Bay occurs year round while in adjacent Macajalar Bay, spawning occurs from October to April only.

FIGURE 2.12
Von Bertalanffy growth model of *Sardinella gibbosa* based on median parameters estimated by BFAR-NSAP VI



Note: TL measurements converted to SL using the following regression based on data collected from the present study: TL = 1.0823 + 1.1063SL (n = 2202; r^2 = 0.9086).

Source: Mesa and Guanco (2011).

This is followed by Gingoog Bay in which spawning occurs from December to February, while furthest east in Butuan Bay, spawning occurs from February to April only. In Zamboanga Peninsula, spawning peaks from September to February (de Guzman *et al*., 2015). In the Visayan Sea, GSI values of *Sardinella gibbosa* suggest that spawning takes place during the northeast monsoon up to March (November to March), at least in monitored areas of the study (Campos, Bagarinao and Nunez, 2019). Seasonal GSI patterns in the northwestern portion of the Visayan Sea (Carles, Iloilo and Milagros, Masbate) are similar but GSI values differ, with fish in Carles showing lower GSI values compared to Milagros.

In the west central portion of the Visayan Sea (Concepcion, Iloilo and Bantayan, Cebu), the seasonal GSI pattern appears to be opposite to that in the northwest and GSI values also differ, with individuals in the waters off Bantayan having two to three times lower GSI. In the western Visayan Sea, typical GSI data show mean values between 2 percent to 3 percent during peak spawning months (2012 to 2013 in Bayate *et al*., 2016; and 2016 in Campos *et al*., 2017; Campos, Bagarinao and Nunez, 2019). These suggest a low overall reproductive capacity of the stock (Campos *et al*., 2017). The higher mean value off Milagros and the low values off Bantayan, are noteworthy. They suggest that spawning is more seasonal but spread out from September through the northeast monsoon months in these areas, and that local conditions (including food abundance and fishing pressure) may lead to geographical differences in seasonality and reproductive capacity in different portions of the stock. It becomes more interesting because the assemblage of larger fish off Bantayan are the ones that show the lowest GSI values.

Fecundity estimates of *Sardinella gibbosa* in Philippine waters show a range of about 5 014 eggs to 73 250 eggs per individual female fish (Table 2.8). *Sardinella gibbosa* in northern Mindanao and Zamboanga Peninsula exhibit higher fecundity compared to the stock in the Visayan Sea, which may be due to the smaller size range in the latter. It should be considered, however, that *Sardinella gibbosa* is the most exploited species in the Visayan Sea and a reduction in reproductive capacity due to overfishing through time cannot be discounted, similar to the case of *Sardinella lemuru* in Zamboanga Peninsula and San Bernardino Strait.

TABLE 2.8
Size at maturity and fecundity of *Sardinella gibbosa* in Philippine waters

Area	Observed size-at-maturity (cm)	Fecundity	Reference
Northern Mindanao & Zamboanga Peninsula	9.8 – 18.0cm TL	5 014–73 250	de Guzman *et al.*, 2015
Visayan Sea	9.5 – 12.5cm SL	3 882–20 055	Campos *et al.*, 2017

Fisheries bycatch and interactions with other ecosystem components

Catches in commercial sardine fishing operations include only small portions of non-sardine species (scads, small mackerels and juvenile tuna) which are usually of commercial importance and have identified market destinations. There are no available figures for spoilage from commercial catches, but these are presumed to be marketed as fish meal. In the municipal fisheries it is common to have mixed targets, even if catches are dominated by one or two species. For example, the fishery for anchovies commonly uses bag nets which in many areas and in certain seasons also catch many early juvenile sardines. In some areas where sardines make up a substantial portion of the catch year-round, like in the western Visayan Sea where they make up < 1 percent to 68.9 percent of the catch (Campos, Bagarinao and Nuñez, 2019), such operations are perceived to contribute substantially to overfishing because too many juveniles are caught. In other areas, such as the Verde Island Pass in southern Luzon (Campos *et al*., 2013) and in northern Zamboanga Peninsula (Campos, Metillo and Acabado, 2016), bagnet and similar fine-meshed net operations target early juvenile sardines but catch juveniles of many other species as well.

In terms of trophic relations, Metillo *et al*. (2018) show various types and sizes of zooplankton as food items for different life stages of *Sardinella lemuru* and relate this to ontogenetic shifts in habitats during the upwelling season. Meanwhile, larvae and juveniles of the same sardine species form the major diet of round scads (especially *Decapterus macarellus*) (Metillo, personal communication), also a major fisheries resource off northern Zamboanga Peninsula. Because of their abundance year-round, it is likely that all life stages of sardines form important food items for other pelagic fish (including *Auxis* spp. and juvenile skipjack tuna) in the area. It has been suggested that banning the catching of early juveniles may have more of an impact on the abundance of other pelagic species that feed on sardines, rather than on the abundance of sardines themselves (Campos, 2014a, 2014b).

Population parameters

Campos *et al.* (2017) have compiled a list of population parameters on sardine stocks of the Republic of Philippines based on available information (Table 2.9). Much of this information was derived from the Fisheries Sector Program Resource and Ecological Assessment reports (BFAR, 1992–1999), as well as from various sources in FishBase (Froese and Pauly, 2016). The compilations of Ingles and Pauly (1984), Corpuz, Saeger and Sambilay (1985) and Lavapie-Gonzales, Ganaden and Gayanilo (1997) were also major sources of information. An obvious limitation of these sources is that most of them need to be updated, especially for those parameters that are directly influenced by fishing intensity (as well as duration of overfishing), such as mortality and exploitation rates.

TABLE 2.9

Mortality and exploitation rates of commercially important clupeid species based on various reports of studies done in different basins in the Republic of the Philippines from the 1950s to the present

Species	M	F	Z	E	Study period	Area or Basin	Reference
Amblygaster sirm	3.04	3.96	7	0.57	83-88	South Sulu Sea	Lavapie-Gonzales, Ganaden and Gayanilo, 1987
A. sirm	2.15	4.75	6.9	0.69	1987	Camotes Sea	Lavapie-Gonzales, Ganaden and Gayanilo, 1987
A. sirm	1.79	3.91	5.7	0.69	00-02	Honda Bay	Ramos *et al.*, 2009
A. sirm	1.87				12-14	Tawi-Tawi	Romero *et al*,. 2014
S. fimbriata	2.99	2.4	5.39	0.44	94-95	Ragay Gulf	Guarin *et al.*, 1996
S. fimbriata	1.78	0.72	2.5	0.29	84-86	Guimaras Strait	Lavapie-Gonzales, Ganaden and Gayanilo, 1987
S. fimbriata	2.12	3.18	5.3	0.6	1987	Tayabas Bay	Lavapie-Gonzales, Ganaden and Gayanilo, 1987
S. fimbriata	2.67	4.17	6.84	0.61	00-02	Visayan Sea	Guanco *et al.*, 2009
S. fimbriata	2.12	3.11	5.23	0.59	09-10	Visayan Sea	Mesa & Guanco, 2011
S. fimbriata	1.63	1.75	3.38	0.52	1959	Manila Bay	Ingles & Pauly 1984
S. fimbriata	2.12	4.44	6.56	0.68	1965	Palawan	Ingles & Pauly 1984
Sardinella gibbosa	2.64	3.96	6.6	0.6	98-02	Visayan Sea	Guanco et al., 2009
S. gibbosa	1.94	7.14	9.08	0.79	09-10	Visayan Sea	Mesa & Guanco, 2011
S. gibbosa				0.5-0.8	03-12	Visayan Sea	Bayate et al. 2016
S. lemuru	1.48	2.13	3.61	0.59	2014	S Zamboanga	BFAR-NSAP IX Region 2016
Sardinella lemuru	1.7	1.508	3.21	0.46	98-02	Southern Visayan Sea	Belga *et al.*, 2002
S. lemuru	3.09	6.87	9.96	0.69	98-02	W/C Visayan Sea	Guanco *et al.*, 2009
S. lemuru	2.14	1.43	3.57	0.4	94-95	Ragay Gulf	Guarin *et al.*, 1996
S. lemuru	2.02	5.24	7.26	0.72	1965	Palawan	Ingles & Pauly 1984
S. lemuru	2.1	5.27	7.37	0.72	78-79	Manila Bay	Ingles & Pauly 1984
S. lemuru	2.1	3.42	5.52	0.62	1981	Ragay Gulf	Corpuz *et al.*, 1985
S. lemuru	2.01	0.53	2.54	0.21	1987	South Sulu Sea	Lavapie-Gonzales, Ganaden and Gayanilo, 1987
S. lemuru	2.53	2.52	5.05	0.5	98-01	Sulu Sea	Mamalangkap, Mokamad and Ayub, 2003

Values in blue were computed using reported mortality estimates provided in the respective reports.

2.1.4 LEGAL AND ADMINISTRATIVE FRAMEWORK

The Philippine Fisheries Code delineates areas where commercial vessels, defined as vessels larger than 3 GT, can operate. Specific provisions in this law reserves the most productive portion of coastal waters (within 15 km from the shore) for municipal (small-scale) fishing. LGUs, which have jurisdiction over these waters, may individually allow commercial fishing within 10.1 to 15 km, but not closer to the shore. Encroachment, however, is widespread and is perhaps the most common issue of concern for municipal fishers. The Philippine Coast Guard and monitoring, control and surveillance vessels of BFAR operate in areas where closed seasons are implemented, but overall effectiveness requires compliance with regulations. There are no formal evaluations of compliance, but visible infrared imaging radiometer suite data for recent years suggest as much as 20 percent of operations still take place within municipal waters (Beniga and Regalado, 2019). While this system detects light intensities used by commercial vessels, there is still a need to verify the information to determine the proportion of small commercial (3 GT to 20 GT) vessels illegally fishing in these areas. This is an important issue because these vessels are not included in the licensing regulations of the BFAR (national government) but are under the jurisdiction of LGUs which invariably issue licences to such vessels and generally have little, if any, capacity or willingness to enforce the law.

Much of the problem with encroachment concerns these small commercial vessels. In the case of the sardine fisheries, these include encircling gillnet, drift net, “small” ring net, purse seine and midwater trawl operations. Recent improvements to the Fisheries Code (RA 10654) include a section providing for a vessel monitoring system to monitor commercial fishing operations. This has yet to be implemented and it is uncertain if small commercial vessels will be part of this system. Discussions for a programme of onboard monitoring on commercial operations targeting small pelagic fishes, including sardines, are being initiated.

Because of the comparatively larger volumes caught by all commercial vessels, regulating them in already over-exploited fishing grounds is important. However, any scheme to regulate commercial catches needs to be balanced with consumer demand because the distribution and transport of catches to consumers is much less wasteful (less spoilage) and much more efficient (cost and quality) with the larger volume of commercial landings. Such operations have onboard facilities for cold storage to reduce spoilage. In contrast, many small commercial (3 to 10 GT) and most municipal fishers do not use ice because of difficulties in access and the additional expense. Hence, particularly during peak season, spoilage, estimated to be about 25 percent for wet fisheries products in general (BFAR, 2018), tends to increase. In addition, when landings frequently exceed local capacity to transport or sell during peak season, prices of the catch drop drastically, adding further to the loss of potential income. Commercial operations have shorter market chains and fixed market destinations (processing plants, canneries, supermarkets, etc.), so transport of goods can be projected and managed more efficiently. They can catch, handle and transport much larger volumes of fish to consumers quickly with much less spoilage. In contrast, municipal and small commercial landings have much less volume from many more vessels or fishers, leading to much less efficient transport. Hence, any reduction of commercial fishing effort can be equated to a reduction in the efficiency of supply to the market, which may not be desirable if the goal is to provide adequate food and attain food security.

Specifically for sardines, the catching of early juveniles is a major concern in many fishing grounds. Studies have shown that as much as 60 to 80 percent of catches from bag nets, lift nets, beach and boat seines in the Verde Island Passage, Visayan Sea and northern

Zamboanga consist of juvenile sardines soon after peak spawning months. In addition, the use of small mesh sizes (< 3 cm) in gillnets increases the proportion of small sardines in the catches. Unfortunately, there is little available data on the fishing effort of these gear types, making viable interventions difficult to formulate. Catches from these gear types also include substantial amounts of anchovies (engraulids), some of which mature at sizes (5 cm to 6 cm SL) smaller than sardines (Bayate *et al.*, 2016; Campos and Malingin, 2019). While catches of anchovies may be sustainable, the amount of juvenile sardines in the catch may contribute to overexploitation of local stocks.

The BFAR has been implementing the NSAP coordinated by the NFRDI since the early 2000s, with regular dock-side monitoring of landed catches at strategic locations within major fishing grounds in all regions of the country. Sardines have been a special focus in the Visayan Sea, northern Mindanao and a few other fishing grounds, where growth, mortality and exploitation rates are routinely estimated each year. However, information gaps do not allow estimates of total production by fishing ground from their data. Year-round reproductive biology studies and effort monitoring, particularly of the municipal sector, are major gaps in the programme, although there are efforts to address these in specific areas.

There is currently an effort to establish and operationalize fisheries management areas (FMAs), ideally with management bodies and science advisory groups to support policymaking and management decisions in an integrated manner, as opposed to relying on LGUs to adopt similar harmonized management measures in their respective waters. Most LGUs do not have the capacity to determine the necessary measures, and building such local capacity is a long-term goal which cannot address the urgency of current situations in most fishing grounds. At the time of writing, the current scheme for FMAs is still in the development stage, with the Visayan Sea in the central Philippines as an initial focal area.

Recently, the National Sardine Management Framework Plan has been formulated with inputs from a science advisory group that includes representatives from academia, research institutes, conservation organizations and BFAR researchers, and consultations with the National Fisheries and Aquatic Resource Management Council and national representatives of fisher organizations from both the municipal and commercial sectors. Widespread consultations were scheduled in 2019. Harvest control reference points include:

- length at first maturity;
- median length of catches;
- spawning potential ratio;
- proportion of juveniles in the catches;
- catch per unit effort of indicator gear types; and
- exploitation rates.

2.1.5 MANAGEMENT MEASURES

Management measures	Description	Effectiveness
Spatial restrictions, e.g. closed areas, marine protected areas (MPAs), etc.		
• RA 8550	Philippines Fisheries Code. Defines municipal waters as all coastal (mainland and island) waters within 15 km from the shore and by design, bans fishing by all commercial vessels (> 3 GT) in this area.	The BFAR issues licences to fishing vessels from 20 GT and larger (medium and large commercial vessels). The small commercial vessel sector (3 GT to 20 GT) are invariably issued permits by the LGU and are implicitly allowed to fish in municipal waters.
• RA 7160	Local Government Code establishing jurisdiction of municipalities and cities over coastal waters within 15 km from the shore.	Boundaries not well-defined for some areas, particularly those with islands. Difficult to implement solely by LGUs. In some areas only resident fishers are allowed, in many others there are no restrictions.
• MPAs	As of 2007, over 1 300 MPAs had been established nationwide, over 50 percent of these have areas less than 10 ha (Alino et al., 2007), focusing primarily on coral reefs. More recent MPAs have included adjacent grass beds and mangroves in their no-take zones, but in general do not include substantial portions of sardine fishing grounds.	As of 2007, only about 10 percent to 15 percent of established MPAs showed some level of implementation. The remainder were "paper MPAs". With the formulation of the local MPA Management Evaluation and Assessment Tool in 2011, more MPAs have been actively involved in implementation.
Temporal restrictions, e.g. closed seasons		
• JAO 1 s. 2011/Fisheries Administrative Order 255 s. 2014	Jointly issued by the DA-BFAR and DILG declaring the area of East Sulu Sea, Basilan Strait and Sibuguey Bay, covering 13 978 km2, closed to fishing specifically for sardines from 15 November to 15 February each year.	LGU implementation for small-scale sector differs in extent and level and also difficult to enforce due to multi-species nature of catches. Largely effective for medium to large commercial vessels, although encroachment into municipal waters is common in all areas.
• Fisheries Administrative Order 167 (1-3)	Establishing a closed season for the conservation of sardines, herrings and mackerel in the Visayan Sea (15 November to 15 February each year).	Same as above.
• Coordinated ordinances of 11 municipalities in Balayan Bay, Batangas for a 22-day closed season on commercial fishing.	Designed to conserve big-eye scad and roundscad resources but affects sardines as well because of multi-species nature of catches.	Jointly enforced by local governments with support from national government agencies (e.g. DSWD) for alternative livelihood; compliance appears to be widespread.

Management measures	Description	Effectiveness
Minimum size		
• Length at first maturity (L_{m50})	Target sizes determined for three species in various fishing grounds in the country.	New (included in National Sardines Management Framework Plan 2019).
• Target minimum spawning potential ratio: 20 percent	Target values for at least two species determined for specific fishing grounds.	Same as above.
Participatory restrictions (e.g. licensing, TURFs, etc.)		
• Fisheries Administrative Order 223/BFAR Circ no. 253 (2014)	Moratorium on issuance of new commercial fishing vessel and gear licenses nationwide as part of precautionary approach.	For three years only; appears to be fully implemented for medium and large commercial vessels.
Limits to fishing capacity (e.g. max. number of vessels; fleet reduction program, etc.)		
Target exploitation rate (0.3–0.5)	Target values determined for multi-species small pelagic fisheries, including sardines; indirect measure limiting fishing effort.	New measure in National Sardine Management Framework Plan but specific limits to be determined once data on fishing effort, particularly the commercial sector, become available.

DA-BFAR: Dept. of Agriculture – Bureau of Fisheries and Aquatic Resources

DSWD: Dept. of Social Welfare and Development

MC: Memorandum Circular

DILG: Dept. of Interior and Local Governments

RA: Republic Act

JAO: Joint Administrative Order

LGU: Local Government Unit (municipalities & cities)

2.1.6 MAIN STAKEHOLDERS

The main stakeholders are the fishers themselves. Based on the last fisheries-directed census (2002), there were a total of 1 614 368 fishers (BFAR, 2018) 85 percent of whom were from the municipal sector, while the rest were from the commercial capture (14 percent) and aquaculture (1 percent) fisheries sectors. Using the average population growth rate of 1.90 percent from the decade 2000 to 2010 (PSA, 2021), the updated estimate for 2018 is close to 2.2 million fishers. If each fisher is head of a household, for an average household size of 4.4 for 2018, the number of individuals directly dependent on fisheries as a source of livelihood is around 9.6 million. The proportion directly involved in sardine fisheries is not known, but it would comprise up to one-third of fishers in the major sardine fishing grounds (Zamboanga Peninsula, northern Mindanao and the Visayan Sea).

The principal issue between municipal and commercial fishing sectors is access to the stock. The commercial sector has lobbied the government to allow it to fish within 15 km of the shore where most of the fish are, to provide adequate supplies of fish to markets around the country. The main issue with small-scale fishers is their dwindling catch, made smaller by encroachment from commercial fishers. Recent estimates from the NSAP indicate that the median catch rates (kgs/trip) of typical commercial fishing gears (purse seines and ring nets) may be as much as 500 times the typical catch rates of municipal gear types (Ramiscal, 2019). Small-scale fishers have been unable to scale up their operations to a more efficient level due to a lack of capital. Since sardine stocks are generally already overfished, allowing any additional fishing anywhere or from any sector would go against efforts geared towards attaining sustainable fisheries.

Fish processors are also among the main stakeholders. In the Visayan Sea, drying is by far the most common method of processing sardines. For the dominant species in the area (*Sardinella gibbosa*), fishers usually do not use ice because they seldom fish in areas over a couple of hours from their base and this species preserves well for at least a few hours. In northern Mindanao, sardines are dominated by a fattier species (*Sardinella lemuru*) which is processed best through canning and bottling. There are 12 canning factories in Zamboanga City and at least nine sardine bottling companies in Dipolog City in northern Zamboanga. An oversupply of fish can be more readily absorbed by these facilities. Nevertheless, areas lacking such facilities are more prone to high rates of dockside spoilage and drastic drops in dockside prices. In the Visayan Sea, seasonal oversupply also leads to spoilage (up to as much as 30 percent) and drastic drops in prices. Interventions aimed at reducing spoilage and maintaining good dockside prices would be helpful, particularly to small-scale fishers, and a general increase in efficiency of the fishery would help attain long-term sustainability.

LGUs (municipalities) are stakeholders in areas where fishing is the principal means of livelihood. Viable fisheries translate into productive livelihoods, more local economic activity and ultimately higher income for the LGU. This in turn allows them to provide better services to their constituents. LGUs are also mandated to manage their own coastal and fisheries resources, but few have developed the capacity to do so. The concept of FMAs harmonizing efforts between LGUs in a fishing ground offers opportunities to build this capacity for the long term.

The wide range of consumers is also an important stakeholder group. Sardines make up a principal food in the Republic of the Philippines and possibly represent the cheapest form of fish protein available to consumers. Canned sardines are staple meals for the military, Bureau of Prisons, and even disaster relief operations, and could serve as a good indicator of the country's economy. Hence, any further reductions in sardine stock abundance, or any improvements in their sustainability, would have far-reaching effects for local consumers.

2.1.7 CLIMATE CHANGE DRIVERS AND EXPECTED IMPACTS

Ocean currents, production ecology, species composition, etc.

- Evidence shows that the changing climate has weakened the massive ocean circulatory system, resulting in profound consequences such as changing rainfall patterns in the tropics, building up of warmer waters in higher latitudes, and shifting primary productivity dynamics, among others. Recent studies have shown that the Republic of the Philippines is among the countries to experience the highest magnitude of increase in ocean temperatures (David *et al.*, 2017) which subsequently results in distortions of current flow. Changes in the intensity of ocean currents in areas like San Bernardino Strait in east central Philippines determine the dynamics and location of oceanographic fronts in the area of Ticao Pass, which in turn are features likely linked to spawning and feeding of early stage sardines in this fishing ground.
- Hydrography also likely plays a major role in larval retention and transport off northern Mindanao (Cabrera *et al.*, 2011 and Villanoy *et al.*, 2011).

ENSO, production ecology, species composition

- High sardine production off the Zamboanga Peninsula is closely linked to the timing of ENSO events (Villanoy *et al.*, 2011).
- Decrease in catch rates of small pelagic fish in the Visayan Sea during ENSO (Armada, 1998).
- Possibly smaller size at hatching for *Sardinella gibbosa* in the Visayan Sea during warmer ENSO events (Campos, 2018).
- Significant intra- and inter-annual variability in early life growth of *S. lemuru* in northern Zamboanga Peninsula. Moderate winds during a "neutral" ENSO year (2012 to 2013) resulted in upwelling conditions favouring faster overall growth in larvae. In contrast, slower growth was observed during weak upwelling conditions in the 2011 to 2012 La Nina year, which may have led to weaker recruitment (Bagarinao and Campos, 2017).

Sea level rise, communities, loss of and damage to assets

- The Republic of the Philippines is among the countries that experience the highest magnitude of increase in sea level, particularly on the Pacific side (David *et al.*, 2017). Rising sea levels have been observed at several sites (Legazpi, Cebu, Davao and Jolo) since the 1970s (Ortiz *et al.*, 2016). In Manila, sea level rose around 0.013 cm^{-yr} (similar to the global rate) until the early 1960s, then increased to about 2.6 cm^{-yr}, which correlates with the increase in metropolitan Manila's use of groundwater until 1995 (Rodolfo and Siringan, 2006). The Republic of the Philippines is projected to be affected by a 51 percent reduction in existing coastal wetland area by 2100, specifically in Ilocos, Cagayan Valley, Central Luzon, central Visayas, and Western Visayas (McLeod *et al.*, 2010).
- Most small-scale fishers will need to relocate further inshore, if there is space available. This will be a major concern in areas with narrow coasts, steep topographic relief and on small islands.

Rainfall, production ecology, species composition

- Increased rainfall strengthens the stratification off northern Zamboanga, leading to reduced upwelling and perhaps reduced larval survival. During La Niña events, the air pressure across the western Pacific is less than average. These low-pressure zones

contribute to increased rainfall in the southeast portion of the world (e.g. Republic of the Philippines, Republic of Indonesia, Republic of India, etc.). More rainfall leads to stronger stratification (density and salinity differences between layers of the water column), requiring stronger than average winds to cause upwelling. In other areas, however, more precipitation may translate to more nutrient inputs to the coast and, provided there is no increase in siltation, may result in higher plankton production and sardine larval survival.
- La Niña years are closely associated with reductions in sardine catches (Villanoy *et al.*, 2011).

Rainfall, communities, adaptation, etc.
- Increased rainfall reduces the drying capacity of processors in all fishing grounds, including the Visayan Sea, where drying is the principal means of processing sardines.

Thermal structure, production ecology, species composition, etc.
- Affects wind systems driving upwelling and formation of oceanographic fronts where associated high primary productivity can be linked to high sardine production.
- In the northern Zamboanga upwelling system, La Niña events are associated with a weakening of upwelling, while the opposite is true during El Niño events (Villanoy *et al.*, 2011). It has been mentioned earlier that slower larval growth which may have led to weaker recruitment was observed during weak upwelling conditions in the 2011 to 2012 La Nina year (weak winds < 3.8 ms^{-1}) (Deauna, 2016) while moderate winds (4.2 to 4.5 ms^{-1}) (Deauna, 2016) during a "neutral" ENSO year (2012 to2013) resulted in upwelling conditions favouring faster overall growth in larvae (Bagarinao and Campos, 2017).
- The intensity of upwelling varies with wind conditions, with optimal productivity resulting from alternating periods of intense and relaxed wind conditions (Garcia-Reyes, Largier and Sydeman, 2014). The calmer periods allow plankton to use nutrients brought to the surface during periods of high intensity winds. The net effect is high biological productivity in the area, with increased primary production and zooplankton populations (Botsford *et al.*, 2006). Moderate winds have been associated with optimum upwelling conditions such that the occurrence of larval patches is well matched with patches of abundant food in space and time, ultimately resulting in enhanced larval survival and recruitment (Cury and Roy, 1989). In the Benguela upwelling system, maximum recruitment of sardines has been observed in years of moderate upwelling with optimum chlorophyll production (Skogen, 2005). In the California Current system, years with moderate winds had the highest surface Chlorophyll a concentrations, with mid-range sea surface temperature values (Garcia-Reyes, Largier and Sydeman, 2014). In the Iberian Peninsula, strong winds corresponded to decreases in sardine catch (Borges *et al.*, 2003). At intra-seasonal and interannual scales, variability in wind strength is strongly influenced by factors like the prevailing monsoon and climate oscillations, such as the Madden–Julian Oscillation and the ENSO (Chang, Wang and Hendon, 2006; Li, 2010).

Storm severity and frequency, fishing operations and communities, safety/loss and damages
- Most fishers use wooden outrigger vessels with limited seaworthiness in rough seas and stormy weather.
- The number of fishing days per year in various fishing grounds in the country is determined largely by exposure to waves and wind (MERF, 2006).

2.2 THREATS TO FISHERIES SUSTAINABILITY

There is enough data to show that sardine stocks off the Zamboanga Peninsula and the Visayan Sea, the two major sardine fishing grounds, are overexploited. Stocks in the other areas are likely to be in a similar situation. Fisheries management interventions need to allow these stocks to recover their biological production potential so they can continue to support fisheries, both as the principal source of livelihood for about two million fishers and their families, and as an industry with substantial contributions to the national economy. There are a number of obstacles to this task, and they pertain to capture fisheries in the country in general.

Encroachment of commercial vessels in municipal waters

As defined by law, LGUs have jurisdiction over their coastal waters extending to 15 km from the coast. Commercial fishing vessels (> 3 GT) are not allowed to fish within this zone. Most LGUs do not have the capacity to police their waters, so compliance is essentially voluntary. As mentioned earlier, about 20 percent of commercial fishing operations still take place in municipal waters. This is further complicated by unclear policies regarding small commercial vessels (3 GT to 20 GT) which are licensed locally by LGUs. Because many local officials are from influential families with ties to small commercial operators, there are few if any restrictions to the latter's fishing activities. Since small commercial vessel capacity will be the direction of any future development plan for the municipal sector and the lack of policy and roadmap prevents any effort to provide the needed support and infrastructure to realize this.

A recent complicating issue is the declining supply of overfished roundscads (*Decapterus* spp.) in local (primarily Metropolitan Manila) markets. Because roundscads are "the common man's fish", the short supply has become an important food security issue, triggering lobbying by the commercial sector to be allowed to fish closer to shore where "fish are still abundant" and small municipal fishers do not have the capacity to catch them all. In late 2018, the government opted to import roundscads from China, stirring up even more controversy.

Inadequate support to the industry from the national government

The decision to invest adequately in many small facilities where small volume landings of municipal and small commercial vessels operate will always be difficult, but more so with the lack of clear policies to guide decision-making. This is perhaps the root cause of the shortage of support for the industry.

Lack of data necessary for management

While there are existing efforts to address this (e.g., NSAP), not all major sardine fishing grounds are covered adequately, and current monitoring protocols need to address gaps in monitoring fishing effort at the municipal level in the future. Harvest control reference points and measures provide clear targets for management plans, but these need to be supported by adequate and representative data. The gaps in historical data have made it difficult to convince stakeholders, including government, of the real status of fisheries production, weakening the determination to formulate and implement the correct interventions.

Enforcement is weak to non-existent in most fishing grounds

While deputized local enforcement teams (*Bantay Dagat*) are common, their activities are often restricted by lack of LGU funds to maintain boats and operations, lack of political will to enforce laws, and lack of coordination with adjacent municipalities. There are areas, however, where LGU alliances are effective and the Provincial Government plays a central proactive role. Such practices need to be duplicated in more areas.

Lack of local capacity to manage fisheries

All LGUs are required by law to form Fisheries and Aquatic Resources Management Councils (FARMCs) at the municipal and constituent barangay (village) levels. These councils consist of representatives of various stakeholder groups and are tasked with implementing fisheries management plans, if such exist. Most LGUs need assistance in formulating management plans for their FARMCs to implement. This is crucial if the recently formed FMAs are to take effect. LGUs need the capacity to monitor local fishing catch and effort to determine which of the many gear types requires special attention (e.g. fine-meshed nets). The absence of data showing the impact of the latter's catches is the primary reason why they continue operating.

Limited participation of science and academia

Information from research studies will not reach policymakers unless they are published or disseminated in forums at which relevant national agencies and LGUs are represented. This has no doubt contributed to the perennial "lack of data" mentioned above. There is a recent effort to establish Science Advisory Groups, with representatives from academia, conservation organizations and BFAR technical staff, at the national and FMA levels.

Inefficient market chain

The structure of municipal fisheries is similar all over the country, with fishers borrowing money from "buyers" whom they pay back with their catches. The "buyers" often transport the fresh catches to the local market or to another trader and so on, depending on how accessible the consumer market is. In island villages, the number of traders is greater, the total cost of transport is more, and the margin of profit becomes smaller, with the smallest amount going to the fisher. While consumer prices have increased substantially in recent years, partly due to the increased cost of transport, the dockside value of catches has not, in spite of increases in the cost of fuel, among many other commodities that fishers also buy. The more traders, the less profit fishers can look forward to. Hence, in the face of an increasing cost of living and dwindling catches, some fishers are forced to use illegal (e.g. fine mesh nets) or even destructive (e.g. dynamite) methods of fishing. If the market chain can be made shorter, with more profit going to the fishers (via value-added processing) management interventions might be more acceptable to more fishers, making the task of attaining sustainability in sardine stocks possible in less time.

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Chapter 3

A baseline report on the socio-economic importance of the sardine fishery sector in the Republic of the Philippines and its vulnerability to climate change

Didi B. Baticados

3.1 INTRODUCTION

The Republic of the Philippines is an archipelagic country comprising 7 107 islands and is the second largest archipelagic country in the world (FAO, 2014). It is endowed with vast marine resources, a coastline stretching 36 289 km and an exclusive economic zone (EEZ) of 2.2 million km^2. The country's shelf area is 184 600 km^2, with a depth of 200 m and a coral reef area of 27 000 km^2.

The Republic of the Philippines sits at the heart of the Coral Triangle, which is a global centre of marine biodiversity (Carpenter and Springer, 2005). With the country's vast marine resources, food security for 104.9 million Filipinos (2017 data) is assured, with enhanced biodiversity and a healthy marine ecosystem. Sardine is among the small pelagic fisheries that comprise an important segment of the country's fisheries industry. Together with anchovies, sardine is the main source of inexpensive animal protein for lower-income groups in the Republic of the Philippines (FAO, 2014). Sardine is a critical component of food webs that contribute to the health and resilience of the ocean (BFAR, 2018a). Sardine forms the building blocks of the oceanic food chain for larger marine predators like sharks, dolphins and tuna (Ramos, 2017).

Sardine biodiversity is high in the Republic of the Philippines (Willete, *et al.*, 2011). *Tawilis* (*Sardinella tawilis*), the only known fresh water sardine species, is found in the country and *Sardinella pacifica* is the most recently discovered sardine species discovered in the Republic (Hata and Motomura, 2019). But like fisheries elsewhere, the productivity and sustainability of the sardine fisheries is threatened by anthropogenic factors, such as overfishing, disease, sedimentation and pollution, among others. Climate change is an added stressor to the already threatened fish species, placing the food security of Filipinos and the livelihood of coastal dwellers who depend on sardine fisheries in danger.

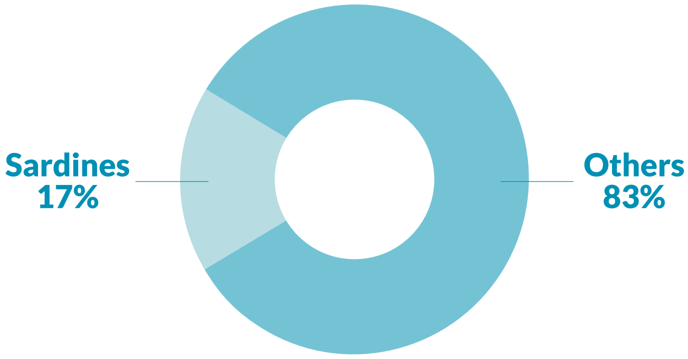
3.2 SOCIO-ECONOMIC IMPORTANCE OF SARDINE FISHERIES IN THE REPUBLIC OF THE PHILIPPINES

National economy

Fisheries is not a dominant player in the Philippine national economy. According to BFAR (2018c), the fisheries sector contributed 1.2 percent and 1.4 percent at current and constant prices, respectively, to the country's GDP in 2017. This corresponds to PHP 197.23 billion for current prices and PHP 122.25 billion for constant prices. Fisheries accounted for 12.9 percent (PHP 197.23 billion) and 16.5 percent (PHP 122.25 billion) of the gross value added in agriculture, fishery, and forestry in current and constant prices.

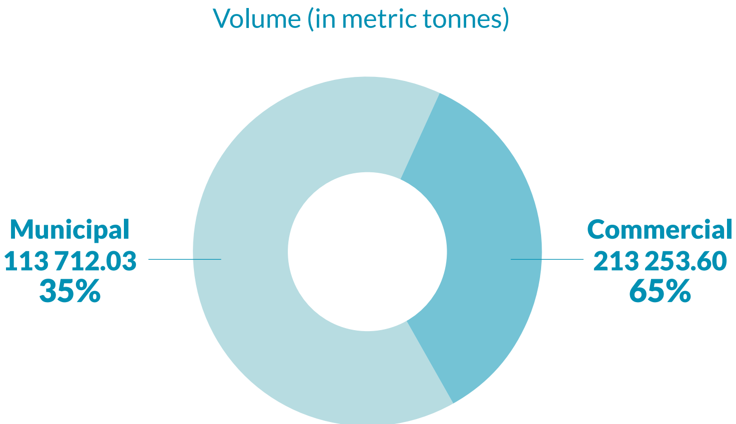
Despite its modest contribution, fisheries still had positive net foreign earnings of USD 475 million (PHP 22 926 million) in 2016. Marine fisheries production was 1 910 428.29 tonnes in 2017 (Figure 3.1). Sardine contributed 326 965.63 tonnes or a 17 percent share of the total, valued at PHP 9 412 027.60. Of the total sardine production, 213 253.60 tonnes (65 percent) came from the commercial sector and 13 712.03 tonnes (35 percent) from the municipal sector. The 65 percent share of the commercial sector is valued at PHP 5 640 522.56 while the 35 percent share of the municipal sector is valued at PHP 3 771 505.04 (Figure 3.2).

FIGURE 3.1
Percentage contribution of sardine to total marine fisheries production, Republic of the Philippines: 2017



Source: PSA, 2018.

FIGURE 3.2
Sardine production in the Republic of the Philippines by sector: 2017



Source: PSA, 2018.

The fishing vessels used to harvest sardine in the Republic of the Philippines are classified as municipal (≤ 3 gross tonnage or GT) and commercial (> 3 GT) vessels. The former operate within the municipal waters and under the jurisdiction of the local government units (LGUs) while the latter operate beyond 15 km from the shoreline and under the Bureau of Fisheries and Aquatic Resources (BFAR). There are 263 405 registered vessels as of August 2018, based on Municipal Fishing Vessels and Gears Registration or BoatR (BFAR, 2018d). Commercial fishing vessels are categorized as small (> 3–20 GT), medium (20–150 GT) and large (> 150 GT). A license has to be secured at BFAR for a commercial fishing vessel to operate, subject to renewal every three years. There are 6 901[1] commercial fishing vessels (BFAR, 2018c), of which 1 180 are for catching small pelagics (Table 3.1). The latter uses purse seine, ring net and bag net to catch sardine.

[1] BFAR is updating data.

TABLE 3.1
Registered commercial fishing vessels and average number of workers per gear for small pelagics in the Republic of the Philippines

Regions	Bag net	Ring net	Sardine/ mackerel/scad purse seine	Total
National Capital Region (NCR)	6	36	95	137
Region 1	1	4	2	7
Region 2	2	32	0	34
Region 3	1	12	6	19
Region 4-A	23	101	9	133
Region 4-B	21	25	4	50
Region 5	10	101	3	114
Region 6	3	14	22	39
Region 7	0	93	12	105
Region 8	1	87	5	93
Region 9	34	27	62	123
Region 10	17	41	2	60
Region 11	3	43	1	47
Region 12		104	82	186
Region 13	7	15	0	22
Autonomous Region Muslim Mindinao (ARMM)	NA	NA	NA	11
Grand total	**129**	**735**	**305**	**1 180**
Average number of workers per gear[2]	13	20	27	
Total workers	**1 677**	**14 700**	**8 235**	**350[3] + 24 612 = 24 962**

Source: BFAR, 2019.

Large vessels, mostly using purse seine nets and targeting sardines exclusively, are found in NCR (95), followed by Region 12 (82), and Region 9 (62). NCR is the home of the Navotas Fish Port, the biggest fish-trading centre in the Republic of the Philippines where exchanges of fishing goods and services are abundant, and where commercial fishing vessels from other regions offload sardine for auction. Region 12 is the centre of tuna canning, while Region 9 is the bastion of sardine canning and bottling. Commercial vessels supply canneries' fresh sardine requirements while municipal boats supply the needs of bottled sardine processors and the like.

Sardine is among the most economically important fish species in the country, and the sardine industries are a major sector of the Philippine economy (FAO, 2014; Narvaez *et al.*, 2018). In commercial fisheries, Indian sardine ranked second (18 percent) to skipjack (23 percent) in terms of major fish species production contribution in 2017. It was followed by roundscad (13.3 percent), yellowfin tuna (7.4 percent), frigate tuna (6.9 percent), fimbriated sardine and big-eye scad (4.4 percent each). The rest of the major fish species accounted for less than 4 percent. Indian sardine is the highest volume (7.4 percent) major species caught in municipal marine waters, followed by big-eyed scad (7 percent), frigate tuna and roundscad

[2] Source: Cruz-Trinidad, 2003.
[3] Actual number of ARMM licensed commercial fishers (BFAR, 2018b).

(5.9 percent each), squid (4 percent), fimbriated sardines and Indian mackerel (3.9 percent each), yellowfin tuna (3.8 percent), slip mouth (3.6 percent) and anchovies (3.5 percent).

In international trade (FAO, 2021), exports of the Republic of the Philippines sardine products increased from 4 171 tonnes in 2005, to 10 766 tonnes in 2008, for the period 2005 to 2016 (Table 3.2). The volume decreased in 2009 but recovered until it peaked in 2011 at 15 516 tonnes. Volume declined again to 3 265 tonnes in 2015 and recovered once more in 2016 to 9 610 tonnes.

In terms of imports, the highest volume was in 2012 at 36 547 tonnes, decreasing thereafter. The lowest import volume (233 tonnes) was in 2006. In parallel to volume, the value of exports also increased until 2008 before diminishing in 2009 and recovering in 2011. The value of exports decreased later but recovered again in 2016 to USD 19 372 000, although it did not reach the 2011 levels. The value of imports was lowest in 2006 and highest in 2012, declining thereafter. Sardine contributed 3.7 percent of total fish exports in 2016.

TABLE 3.2

Volume and value of exports and imports of sardine in the Republic of the Philippines, 2005–2016

Year	Volume (tonnes)		Value (USD 000)	
	Export	Import	Export	Import
2005	4 171	11 314	6 727	3 755
2006	5 745	233	8 868	135
2007	9 167	2 014	16 980	845
2008	10 766	955	21 457	414
2009	7 851	1 736	15 320	749
2010	8 661	4 033	16 994	1 608
2011	15 516	7 874	23 893	4 082
2012	10 244	36 547	16 072	19 256
2013	6 714	28 597	11 385	16 051
2014	5 852	22 480	10 032	12 032
2015	3 265	9 046	5 440	5 384
2016	9 610	7 327	19 372	4 728

Note: Sardines, sardinellas, brisling or sprats, fresh or chilled; sardines, sardinellas, brisling or sprats, frozen; sardines, sardinellas, brisling or sprats, prepared/preserved, not minced.

Source: FAO, 2021.

Generally, 20 percent of Philippine fish production is exported while 80 percent is consumed locally. Of the latter, 64 percent is sold fresh, 8 percent is dried and 8 percent is processed (BFAR, 2005). The total revenue of 131 establishments processing and preserving fish, crustaceans and molluscs was PHP 47.4 billion in 2014, based on the 2015 survey of manufacturing establishments with 20 or more employees (PSA, 2017a). The domestic consumption of canned sardine was 10 680 000 cases in 2014 (Tuna Canners Association of the Philippines, 2015). Of these, an average of 7 707 monthly or 8 492 400 cases annually are produced in Region 9 (Narvaez *et al.*, 2018). In the past few years, sardine generated a value of around PHP 10 billion (Mega Global, 2019). In 2018, the total annual revenue from the canned sardine industry was PHP 12 billion (C. Cruz, pers.com, 27 March 2019) making canned sardine a prime economic contributor to the country's economy. The average selling price is PHP 1 750 per case. One case contains 100 cans of 155 grams each. Of the total production volume, about 10 percent is exported at PHP 2 980 per case.

A review of the marine fishery production, however, showed a declining trend between 2013 and 2017 (Table 3.3). The commercial production decreased (–11.18 percent) more than the municipal marine fisheries production (–9.41 percent). In the case of sardine production, it was the reverse. Sardine commercial production increased by 2.48 percent in 2017 compared to production in 2013, while the sardine municipal production decreased by almost the same amount (–3 percent) though there was some variability in intervening years. Overall, the marine fisheries production in 2017 was down by 10 percent from 2013, while the sardine production had a zero growth rate in 2017.

TABLE 3.3
Volume of marine fisheries and sardine production by sector, Republic of the Philippines: 2013–2017 (tonnes)

Sector	2013	2014	2015	2016	2017	Decrease/ Increase (2013-2017)
Marine fisheries production						
Commercial	1 067 610.33	1 107 220.80	1 084 624.70	1 016 948.05	948 281.45	(11.18 %)
Municipal	1 062 147.63	1 029 394.45	1 011 792.73	976 941.19	962 146.84	(9.41 %)
Total	2 129 757.96	2 136 615.25	2 096 417.43	1 993 889.05	1 910 428.26	(10 %)
Sardine production						
Commercial	208 087.47	245 226.18	261 871.78	246 328.83	213 253.60	2.48 %
Municipal	117 592.26	110 837.36	118 438.81	118 620.47	113 712.03	(3.30 %)
Total	**325 679.73**	**356 063.54**	**380 310.59**	**364 949.30**	**326 965.63**	**0 %**

Source: PSA, 2018.

Livelihood and employment

Apart from contributing to the economy, the sardine industry provides a livelihood and employment to many people belonging to different socio-economic strata, including the coastal fishing communities, traders, processors, exporters and workers in ancillary services.

In 2015, about 2.38 percent of the Philippine population 15 years and older was economically active in the sardine fishery sector[4]. However, it is difficult to ascertain the proportion of

[4] See p.79, par. 1 for the limitation of the study.

the population economically active and employed upstream and downstream in sardine fishery activities because information is scant and limited to major players in the industry (BFAR, 2018d).

Municipal fisheries provide a livelihood to most coastal dwellers in the country. Israel, Lunod-Carinan and Paqueo (2016) claimed that employment in sardine fishing in the country is unknown but considered it substantial. Nonetheless, there are about 1.6 million people engaged in fishing and related activities as of the 2002 National Statistics Office (NSO) census, accounting for about 5 percent of the labour force. About 85 percent (1.3 million) of them are in the municipal (inland and marine) fisheries, 1 percent in commercial fisheries and 14 percent in aquaculture. Recent data from the BFAR FishR lists 1 946 955 (1 347 100 or 69 percent, male; 599 855 or 31 percent, female) fisherfolk as of May 2019 (BFAR, 2019). About 24 962 commercial fishers are engaged in harvesting sardine based on the average number of workers per gear used in targeting small pelagics.[5] This implies that there are now more fishers relying on capture fisheries. Data on those employed in the ancillary services[6] sector is not available as this is not well documented (BFAR, 2018d).

Nonetheless, Zamboanga City (Region 9), which is considered the "sardine capital" of the Republic of the Philippines, and a base for most big industry players (Annex 3.1) is a PHP 3 billion industry. The commercial sardine industry employs about 35 000 workers, which includes 12 canning factories, 25 active bottled sardine processors, ten establishments in allied industries, four tin can manufacturers, four industry associations, 20 commercial fishing operators, 2 046 licensed municipal fishers, and 588 licensed vessels (DTI-9 2013; DTI, 2014 in Brillo *et al.*, 2016; Narvaez *et al.*, 2018).

Their voice, particularly the canned and bottled processors and the commercial fishing vessel (CFV) operators, was a factor in implementing a closed season policy in 2011 in the region. Region 9 supplies 75 percent of the country's total domestic requirements for canned sardines (DTI, 2021). The bottled sardine industry is gaining ground and is now making inroads into the export market (DTI, 2021). Dipolog City in Region 9 pioneered the production of in-glass or bottled sardines in the country, earning the name "Bottled Sardine Capital of the Philippines". Bottling sardine, likewise, became a platform for cooperative livelihood initiatives among coastal dwellers who have little or no capital. National government agencies and non-government organizations (NGOs) help these cooperatives or associations by providing value-adding technologies, enhancing post-harvest facilities, and fostering market linkages.

The 2015 Annual Survey of Philippine Business and Industry (PSA, 2017b) also shows that about 52 035 workers are employed in the fisheries sector (27 percent) and fishery-related establishments (73 percent) associated with the sardine fishery (Annex 3.2).

Food security and nutrition

Sardine contributes 11 percent of the total fish food supply in the country. Almost 80 percent to 90 percent of sardine catch from CVAs, particularly in Region 9, is processed in canneries

[5] See Table 3.1 for details.
[6] Republic Act (RA) 8550 defines ancillary industries as firms or companies related to the supply, construction and maintenance of fishing vessels, gears, nets and other fishing paraphernalia; fishery machine shops; and other facilities such as hatcheries, nurseries, feed plants, cold storage and refrigeration, processing plants and other pre-harvest and postharvest facilities. RA 8550 is the Philippine Fisheries Code of 1998. (Government of the Republic of the Philippines, 1998a).

(Narvaez *et al*., 2018). In the Republic of the Philippines, canned, bottled, smoked, and dried sardines are the processed products. In some cases, sardines are fermented or made into paste or sauce. Most sardines, however, are canned for domestic consumption (World Fishing & Aquaculture, 2009) and some are sold abroad along with other processed products.

In 2015, Filipinos' mean per capita consumption of fish and fishery products was 36.8 kg per year. Sardine contributes 1.7 kg of every 24.7 kg of fresh fish consumed each year. Sardine and other fish species share in 4.2 kg/year of dried fish (sun-dried fresh fish), and 3.6 kg of 4.9 kg processed fish (canned)/year (BFAR, 2018c).

Sardine is one of the most staple items in every Filipino home because of its affordability. Along with mackerel scad and milkfish, canned fish and sardine are the three most commonly consumed products by Filipinos, followed by tilapia (Needham and Funge-Smith, 2015). Sardine is rich in Omega-3 fatty acids that reduce the occurrence of cardiovascular diseases and stabilize cholesterol levels (Mega Global, 2019). Studies also suggest that regular consumption of Omega-3 fatty acids reduces the likelihood of developing Alzheimer's disease (Gómez-Pinilla, 2008). Sardine is also a good source of amino acids and proteins that are essential for human growth.

Additional information

For administrative purposes, the Republic of the Philippines is divided into 17 regions based on geographical, cultural and ethnological characteristics (Figure 3.3). Of the 17 regions, only Cordillera Administrative Region (CAR) does not produce sardine because it is landlocked.

FIGURE 3.3
Map showing the administrative division of the Republic of the Philippines by region

Source: PhilAtlas (2019)[7].

[7] ARMM is currently known as Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) per Republic Act no.11054 of the Philippines and ratified in a plebiscite in January 2019.

Table 3.4 shows the three most abundant sardine species in the country:

- Indian sardine(74 percent);
- fimbriated sardine (24 percent); and
- round herring (2 percent).

Region 9 was the highest producer of Indian sardine in 2017, followed by Northern Mindanao (Region 10), and ARMM. Production of fimbriated sardine is highest in Region 5, followed by Region 6 and Region 9. Region 6 is a major producer of round herring, followed by Region 4B and Region 5. Overall, Region 9 is the highest producer of sardine (47 percent), followed by Region 5 (11 percent).

TABLE 3.4
Volume of sardine production in the Republic of the Philippines by species and by region, 2017

Volume (in tonnes)

Region	Fimbriated sardine (*Tunsoy*)	Indian sardine (*Tamban*)	Roundherring (*Tulis*)	Total	Percent of total
NCR	1 253.52	11 936.73	113.31	**13 303.56**	4 %
CAR	0.00	0.00	0.00	**0.00**	0 %
R1 (Ilocos Region)	59.26	103.38	64.01	**226.65**	0 %
R2 (CagayanValley)	504.83	716.01	78.78	**1 299.62**	0 %
R3 (Central Luzon)	1 889.73	2 125.12	363.43	**4 378.28**	1 %
R4-A (Calabarzon)	5 194.72	9 510.52	44.68	**14 749.92**	5 %
R4-B (Mimaropa)	4 948.38	8 376.72	1 046.45	**14 371.55**	4 %
R5 (Bicol Region)	25 026.98	9 208.72	963.11	**35 198.81**	11 %
R6 (WesternVisayas)	12 785.77	10 959.69	2 232.79	**25 978.25**	8 %
R7 (Central Visayas)	4 253.66	2 842.41	45.51	**7 141.58**	2 %
R8 (EasternVisayas)	3 052.98	4 341.69	246.34	**7 641.01**	2 %
R9 (Zamboanga Peninsula)	11 019.06	141 952.59	173.66	**153 145.31**	47 %
R10 (NorthernMindanao)	3 460.92	18 647.43	121.92	**22 230.27**	7 %
R11 (Davao Region)	145.07	1 696.80	4.20	**1 846.07**	1 %
R12 (Soccsksargen)	86.40	1 529.99	14.92	**1 631.31**	0 %
R13 (Caraga)	1 470.80	4 505.22	125.36	**6 101.38**	2 %
ARMM	4 269.71	13 024.35	428.00	**17 722.06**	5 %
Total	**79 421.79**	**241 477.37**	**6 066.47**	**326 965.63**	**100 %**
Percent share	24 %	74 %	2 %	**100 %**	

Source: PSA, 2018.

Sardine production has been affected by anthropogenic factors, including problems in the West Philippine Sea where fishers were restricted from fishing for a period. Sardine beaching was noted in some parts of the country, e.g. Mandaon municipality in Masbate province, provoking contrasting reaction from Oceana Philippines – which attributed the occurrence to environmental stress – and from BFAR, which attributed the occurrence to a positive outcome because of the closed season (Mayuga, 2018). A scientific study is needed to explain and understand the phenomenon.

3.3 CLIMATE CHANGE AND THE SARDINE FISHERIES SECTOR

The World Risk Index ranks the Republic of the Philippines third out of 171 countries most at risk of natural disasters (52.46 percent exposure) (Welle and Birkman, 2015). It is fifth in the Long-Term Germanwatch Climate Risk Index for 1996 to 2015 (PAGASA, 2018b). The country is also situated along the "Pacific Ring of Fire", an active zone for earthquakes and tsunamis.

According to Government of the Philippines (2021), the climate in the Republic of the Philippines is tropical and maritime. It is characterized by relatively high temperatures, high humidity and abundant rainfall. With the onset of climate change, the country's normal climate pattern has also changed. There is now an increase in atmospheric temperature as well as high variability in the frequency and intensity of extreme weather disturbances. Climate change is an added challenge for the sardine-producing communities' socio-economic development and their progress, depending on their adaptive capacity toward the effects of climate change (Nieves *et al.*, 2009, Jacinto *et al.*, 2015).

Sardine is at the base of the food chain and therefore it is sensitive to environmental changes. Abundance is affected by upwelling, circulation, sea temperature, ENSO, monsoons, rainfall and river discharge, all of which can be associated with climate change (Villanoy *et. al.*, 2017). Human activity also directly and indirectly influences the quality and quantity of sardine, such as industry demand and management policies, among other things. It is in this context that the different components of risk (hazards, exposure and vulnerability) – following the 2014 risk framework by the Intergovernmental Panel on Climate Change (IPCC) in Oppenheimer *et al.*, (2014) – are discussed below.

3.3.1 HAZARDS

Colburn *et al.* (2016) identified sea level rise and typhoons as key stressors of climate change that directly affect fishing communities. In contrast, ocean temperature or temperature anomalies and ocean acidification indirectly affect fishing communities.

Temperature anomalies and rainfall

According to PAGASA (2018a), the sea surface temperature anomaly (SSTA) in the tropical Pacific is known as ENSO. El Niño is the warm phase of ENSO with an established SSTA threshold of 0.5 ^{0}C or higher during a three-month period. ENSO is a natural phenomenon resulting from the interaction between the ocean and atmosphere in the central and eastern equatorial Pacific. El Niño can last eight to 12 months and occurs every two to seven years in varying intensities. The strongest El Niño occurs every 10 to 15 years.

PAGASA (2018b) observed that the country is warming at an average of 0.1 °C each decade. The mean air temperature is projected to increase in the mid twenty-first century (2036 to 2065) by as much as 0.9 °C to 1.9 °C (assuming moderate emissions, representative concentration pathway [RCP] 4.5) and 1.2 °C to 2.3 °C (assuming high emissions, RCP8.5). At the end of the twenty-first century (2070 to 2099), the conditions will be warmer, with an increase in mean air temperature relative to the baseline climate from 1.3 °C to 2.5 °C (based on RCP4.5) to between 2.5 °C and 4.1 °C (based on RCP8.5) (PAGASA, 2018b).

La Niña is the cool phase of ENSO which can last one to three years and occurs every three to four years. With El Niña, the Republic of the Philippines will experience an early rainy season in April and a short dry season. PAGASA observed increasing trends in annual and seasonal rainfall in many parts of the country, but the projected change in rainfall is within natural rainfall variations. However, for 2020 to 2050, rainfall is projected to increase in most areas in Luzon and Visayas during the south-east monsoon, but decrease in most provinces in Mindanao (PAGASA, 2011). Above normal monsoon activity causes flooding.

In summary, trends of extreme heat and rainfall indicate a significant increase in the number of hot days, and a decrease in cool nights. The Republic of the Philippines will be warmer by around 2 °C assuming moderate emissions. Extreme heat (> 3 °C) results in a high sea level rise, ocean acidification, and migration of wild stocks to more temperate waters. This will negatively affect fisheries yield and cause a loss in biodiversity because of coral bleaching, which could result in the modification of the distribution of resources (Santos, Dickson and Velasco, 2011) affecting the food and livelihood of coastal communities.

Upwelling significantly increases during El Niño, but dramatically decreases during La Niña (Mega Global, 2019). Upwelling stimulates the growth and reproduction of phytoplankton that sardine feed on. Thus, the sardine catch in Region 9 was higher during El Niño (2003, 2004, 2007) compared to non-El Niño years (Villanoy *et al.*, 2011 in Damatac and Santos, 2016). Damatac and Santos (2016) also noted that the study of Cabrera *et al.* (2011) in the Bohol Sea revealed that a barrier layer may inhibit upwelling during El Niño. These contrasting findings imply that the effect of El Niño varies according to the fishery.

Ocean acidification

Ocean acidification refers to decreasing levels of pH in the ocean, making the sea more acidic (University of California, Davis, 2021). It is caused by the long-term change in seawater chemistry due to the absorption of carbon dioxide from the atmosphere. According to the National Oceanic and Atmospheric Administration, the pH of surface ocean waters has fallen by 0.1 pH units, an increase in ocean acidity of about 30 percent, since the beginning of the Industrial Revolution.

Ocean acidification under saturates the calcium carbonate needed to build the exoskeletons and shells of calcifying organisms, including corals. Without calcium carbonate, shells grow slowly and become weak. Coral reefs with breakable, slow-growing corals erode more quickly than they accrete. Thus, reefs can disappear, and the extinction of an entire species is possible. As seawater becomes more acidic, the less calcium carbonate it can hold, potentially inhibiting the ability of coral reefs to recover from disturbance, even if CO_2 emissions are reduced or eliminated.

Ocean acidification levels are projected to grow 144 percent by the twenty-first century if CO_2 emissions continue. The 2016 Low Carbon Monitor Report predicts that 98 percent of coral reefs in Southeast Asia will die by 2050 (Schaeffer *et al.*, 2016 in Philippine, Climate Change Commission, 2018). Accordingly, the IPCC Fifth Assessment Report cited in the

Philippine Climate Change Commission (2018), projects that between 2051 and 2060, the maximum fish catch potential of the country will decrease by almost 50 percent compared to 2001 to 2010 levels if climate change is not mitigated. This could compromise the long-term viability of these ecosystems and could impact the estimated one million species that depend on a coral reef habitat.

Studies are being conducted at the Marine Science Institute, University of the Philippines, Diliman, to help coral adapt to or buffer themselves from the effects of ocean acidification (San Diego-McGlone, 2017). Senate Bill 3126, known as the "Ocean Acidification Research and Monitoring Act of 2009" was passed for this purpose.

Sea level rise

Coastal tide-gauge records around the Republic of the Philippines indicate a general pattern of increased sea levels over the past 50 years (Kahana, *et al.*, 2016). Sea level rise was observed in certain parts of the Republic of the Philippines from 1993 to 2015 (PAGASA, 2018b; Kahana *et al.*, 2016). The increase in sea level is due to ENSO and the Pacific Decadal Oscillation, and partly due to anthropogenic signals such as land subsidence and groundwater extraction (Rodolfo and Siringan, 2006 in Kahana *et al.*, 2016). The mass loss from glaciers and from the Greenland and Antarctic ice sheets also accelerates sea level rise in the country due to gravitational effects (Kahana *et al.*, 2016).

The Climate Change Commission (2018) reported that the observed sea level rise in the country is three times (60 cm) higher than the global average of 19 cm since 1901. This exposes 60 percent of the country's coastal provinces (64), municipalities (822) and major cities (25) to risk and they will require some relocation. In particular, coastal areas in east Samar and Mindanao and the southern coast of Zamboanga and Negros are at higher risk based on satellite observation (Kahana *et al*, 2016). Sea level rise is projected to further increase by 20 cm to the projected mean sea level by the end of the twenty-first century, regardless of greenhouse gas emissions (PAGASA, 2018b).

The destructive force of sea level rise will manifest mainly during extreme events as seen during Typhoon Haiyan in 2013, which caused an unprecedented storm surge of between five and six metres (Philippine Climate Change Commission, 2018). This typhoon flattened communities along the eastern seaboard of Leyte and Samar, including sardine-producing communities.

Sea level rise will also contribute to coastal flooding, shoreline erosion, salinization of coastal freshwater aquifers and damage to coastal defences (Kahana *et al.*, 2016). Mitigation for coastal flooding risk, for example building sea wall structures, should be based on local changes and not on flooding recurrence. Tectonic movements and seismic activity, along with human-built modifications such as sand extraction or dredging of sand for land reclamation, should be considered (Kahana *et al.*, 2016).

Extreme weather

The Republic of the Philippines is a typhoon-prone country with an average of 20 tropical cyclones occurring or crossing the Philippine area of responsibility annually (PAGASA, 2011; Cayanan *et al.*, 2011; Cinco *et al.*, 2016) (Table 3.5). Typhoons, peak in July and August, coinciding with the southwest monsoon months which start late May to September. The southwest monsoon brings 43 percent of the average annual rainfall to the Republic of the Philippines and is enhanced by tropical cyclones, causing flash floods over low-lying areas and landslides along mountain slopes, particularly in Luzon (Cayanan *et al.*, 2011).

TABLE 3.5
Typhoon occurrence in the Republic of the Philippines, 2013–2018

Type	Tropical cyclone frequency, by type and year					
	2018	2017	2016	2015	2014	2013
Tropical depression	6	5	1	1	5	6
Tropical storm	5	8	3	2	5	9
Severe tropical storm*	2	5	1	3		
Typhoon	8	4	8	9	9	10
Super typhoon*			1			
Total	**21**	**22**	**14**	**15**	**19**	**25**

* terminology adopted by PAGASA as of 1 May 2015

PAGASA (2018b) observed that in the past 65 years (1951 to 2015) the number of typhoons entering the Philippine area of responsibility decreased slightly. However, there was a minimal increase in the frequency of very strong typhoons and maximum sustained wind speeds exceeding 170 kph between 1980 and 2015.These trends are predicted to continue over the coming years, with high variability year-to-year in the frequency of occurrence and intensity, especially during an El Niño event.

As it is located within the hotspot for sea level rise and increasing frequency of typhoon intensity, the Republic of the Philippines must adopt risk reduction and management strategies as well as adaptive strategies for climate change to mitigate impacts (Cinco *et al.*, 2016). Without these measures, extreme events will wreak havoc on human settlements, damage public infrastructure, and place a strain on food production and health systems (La Viña, Reyes and Labaria, 2017). Coastal communities, particularly fishers, are the most exposed to these hazards because they are the most socially and economically vulnerable in poverty incidence, second only to farmers (PSA, 2017b). Their fish catch is affected by reef degradation from coral bleaching and fish migration. If left unmitigated, a low fisheries yield will ultimately increase food prices, threaten food security in the country, and exacerbate poverty in rural areas.

3.3.2 EXPOSURE

Exposure is the degree to which people, livelihoods, infrastructure, ecosystems, environmental functions, services and resources, or economic, social or cultural assets in places and settings could be adversely affected by climatic events or hazards (IPPC, 2014 in Oppenheimer *et al.*, 2014).

Fishing grounds, sardine catch and fishing vessels

Exposure of fishing grounds to temperature anomalies may result in fish disturbance and migration (Nieves *et al.*, 2009; Santos *et al.*, 2011; Jacinto *et al.*, 2015). The nil percent average annual growth rate (AAGR) on the total volume of sardine production between 2013 and 2017 may be indicative of temperature anomalies, although overfishing and other anthropogenic factors are not discounted (Table 3.6). Sardine catch in the municipal sector also shows negative AAGR despite the closed season imposed on major fishing grounds for sardine (Annex 3.3). Indian sardine, however, has a 2 percent AAGR when the sardine is classified according to species, which was 13 percent up in 2015, but down again in succeeding years.

TABLE 3.6
Volume of sardine production in the Republic of the Philippines by species, 2013–2017

Year	Volume (in tonnes)			
	Fimbriated sardine (*Tunsoy*)	Indian sardine (*Tamban*)	Round herring (*Tulis*)	Total
2013	89 136.27	229 234.88	7 308.58	**325 679.73**
2014	93 269.83	256 096.49	6 697.22	**356 063.54**
2015	83 842.34	290 654.57	5 813.68	**380 310.59**
2016	76 585.73	280 472.75	7 890.82	**364 949.30**
2017	79 421.79	241 477.37	6 066.47	**326 965.63**
Total	**422 255.96**	**1 297 936.06**	**33 776.77**	**1 753 968.79**
Percent share	24 %	74 %	2 %	**100 %**
AAGR	–3 %	2 %	–2 %	**0 %**

Source: PSA, 2018.

Region 9 (Zamboanga Peninsula) generated the highest volume of sardine production, contributing 47 percent of the total production in 2017, followed by Region 5 (11 percent). All other regions generated less than 10 percent of total production each (see Table 3.4). The productivity of the resource, particularly in Region 9, is often impacted by localized typhoons (Jacinto *et al*., 2015), and is aligned with PAGASA's 2013 projections of increased seasonal temperature, rainfall and frequency of extreme events in the area. Reduced catch, if not contained, may trigger an increase in fish prices, as it did in 2011 when the price of fresh fish jumped 10.8 percent, followed by a subsequent increase in the price of canned sardine (Remo, 2012). The cost of fresh sardine accounts for about 40 percent to 60 percent of total production costs. Canned sardine prices are also politically sensitive owing to the product's status as a staple item, along with rice, in the diet of many low-income Filipinos (World Fishing and Aquaculture, 2007).

It must be noted that a closed fishing season was imposed three months per year for three years (2011 to 2014) in Region 9 under administrative order DA-DILG JAO-01 s. 2011 in designated areas for harvesting sardines and other related species, beginning December 2011. This was premised on a 41 percent decline of sardine fish catch in the region in 2011 and on National Stock Assessment Programme (NSAP) data showing 60 percent to70 percent sardine exploitation (PSA, 2015; Brillo *et al*., 2016; Narvaez *et al*., 2018). There was, however, an unexpected drop of 12.9 percent in commercial catch in 2013 that puzzled most industry stakeholders considering it was the second year of closed season (Brillo *et al*., 2016; Narvaez *et al*., 2018). There was no El Niño in 2013, but it was the world's fourth hottest year recorded since 1880 (Borenstein, 2014), which may have affected the abundance of sardine. No studies, however, have been undertaken to investigate the cause of the low yield.

Extreme weather conditions also alter the normal fishing and marine-related activities of people working in the sardine fishery industry. Fishing expeditions, both by municipal and commercial fishing vessels, are restricted by strong winds and big waves. The fishers' safety and fishing efficiency are, likewise, hampered. For instance, the decrease in the volume of sardine production in Zamboanga City in the last quarter of 2017 and decreased unloading of sardine in Navotas Fish Port, were attributed to fewer fishing expeditions due to weather disturbances (PSA, 2018). Commercial fishers in Zamboanga reduced their fishing activity during the first quarter of the year because Indian sardines caught were not the ideal size for canning, or even for export to other provinces. Smaller than normal size sardine is indicative of overfishing and temperature anomalies. Overfishing is already a major threat to resource productivity, and coral bleaching could worsen the situation (Wilkinson and Hodgson, 1999).

The productive assets of fishers, such as fishing vessels and fishing paraphernalia, are also exposed to inclement weather. During typhoon Haiyan, for example, two-thirds of small-scale fishers in affected communities lost their productive assets (FAO, 2015a). FAO (2015a) also claimed that in regions 4-B, 6 and 8, about 30 000 fishing boats were destroyed, which had an effect on the overall quality of life of fishers because of a loss of livelihood – particularly that of women who play a role in post-harvest activities. The 263 405 municipal vessels listed in BoatR will most likely be damaged during extreme events. Municipal fishers protect their productive assets by towing the boats to higher ground ashore or to rivers or coves for refuge during inclement weather.

Apart from climate disturbances, municipal fishers have to compete with CFVs for resource extraction. The 1998 Fisheries Code gives the LGUs the option of allowing commercial fishing to operate in the area between 10.1 km and 15 km from shore. The ambiguity of the provision became the most contentious issue facing the coastal resource management alliance of contiguous municipalities when one municipality allowed operation of commercial vessels within the 10.1 km to 15 km area (Baticados, Siar and Garcia, 2004). Municipal fishers also claimed that their decreasing catch over the past 20 years was due to the increase of CFVs and their encroachment on the municipal waters (Banks and Leadbitter, 2010; Jacinto *et al*., 2015).

In contrast, the 1 180 CFVs targeting small pelagics operate offshore and stay at sea for long periods, hence they are more exposed to extreme weather conditions. Harsh environmental conditions combined with hard labour, long working hours, and hazardous working conditions, among other things, affect fishing safety (Rezae, Brooks and Pelot, 2016). CFVs, however, have radio communication facilities onboard to ensure safe operation. Thus, commercial fishers may opt to go to another fishing ground where they can safely operate or seek shelter if the situation is considered dangerous. In terms of the magnitude of the impact of extreme events, however, more municipal fishers will lose their livelihood than commercial fishers.

Fisheries infrastructure

In the Republic of the Philippines, fish catches are landed in government-owned and operated fish ports, traditional landing centres and privately-owned facilities (BFAR, 2018d). Government-owned fish ports and landing centres are managed either by the Philippine Fisheries Development Authority (PFDA), or by the LGUs, or are jointly managed by both. There were 116 municipal fish ports in 2017 and 46 private municipal fish ports (BFAR, 2018d). The latter are found in Region 11 (6), Region 12 (12), Region

4-A (11) and Region 4-B (17). The PFDA manages eight regional government-owned landing centres, which include piers, quays and market bays, and co-manage one with the LGU. Baseline data, however, is still needed to account for the operation and number of traditional landing centres (BFAR, 2018d). Nonetheless, BFAR completed the construction of 343 Community Fish Landing Centres as of December 2017, to improve municipal fisherfolk's access to post-harvest facilities. Most commercial catches, however, are landed and traded wholesale in traditional landing centres, which are open to the elements and to adverse conditions. Other landing centres are sturdier, but the damage is also costlier should extreme events occur. The Navotas Fish Port Complex, for example, is a PHP 88 million infrastructure catering to the needs of the fishery sector. It is the sector's centre of commerce with markets, ice plants and cold storage, fish processing facilities, canneries (sardine and tuna), and shipbuilding facilities, restaurants, a fuel depot, gasoline stations and other facilities (PFDA, 2021). Losses in property and livelihood will amount to millions of dollars if operations stop due to climatic disturbance. Nine PFDA-managed landing centres are already non-operational due to damage from typhoons or earthquakes. Proximity to the coastline also makes these facilities vulnerable to sea level rise. Relocating these facilities further away from consumers will alter the movement of people and the physical landscape, among other things, which may have a positive or negative impact on communities.

Shore-based sardine-related businesses

Extreme events and a decline in the resource will affect shore-based businesses like fish markets, processors and ancillary services, among others. For instance, the PHP 3 billion sardine industry in Region 9 stands to lose the most in terms of economic value if the impact of climate change is not mitigated. Some big processors and commercial fishing companies in Region 9 have recognized the need for sustainability and practiced "self-regulation" prior to the 2011closed season policy (Brillo *et al.*, 2016). However, this is not enough to ease the impact of climate hazards. Most processors in the country are micro, small and medium enterprises using traditional fish processing methods like salting, drying and smoking (BFAR, 2018d; BFAR, 2005) and will also lose what little they have due to extreme events.

Workers in fish manufacturing industries (see Annex 3.2) such as canning, packing, processing, drying and smoking involve 7 210 (44 percent) male and 9 163 (56 percent) female workers as of November 2015(PSA, 2017b). This indicates that women are not excluded from fishery-related land-based activities, but they will suffer the most from the impact of climate hazards (WHO (n.d.) in Philippines Climate Change Commission, 2018). The same survey also showed that there are 21 764 workers employed in boat and shipbuilding, and repair establishments. BFAR (2018d) also claimed that there are 80 ship and boatyards as of September 2017 and 239 accredited cold storage establishments. All these establishments, including their employees, will be affected by climate change.

As it is, employment opportunities in coastal areas are scarce, as shown in Table 3.7. Limited skills and low education prevent fisherfolk from moving to other employment elsewhere (Ferrer, 2016). Many studies also found that fishers are reluctant to leave the industry even under adverse economic conditions as they have difficulty in adjusting to non-fishing jobs (Pollnac *et al.*, 2008 and 2014 in Colburn *et al.*, 2016) as fishing is the only job they know.

TABLE 3.7
Livelihood of fisherfolk in Regions 9 and Autonomous Region in Muslim Mindanao, Republic of the Philippines

Region	Capture fishing	Aquaculture	Fish vending	Gleaning	Fish processing	Others
Region 9	32 443	10 905	3 863	8 823	1 548	9 623
ARMM	102 996	45 278	17 167	23 251	9 363	16 765
Total	**135 439**	**56 183**	**21 030**	**32 074**	**10 911**	**26 388**

Source: FishR, 2019.

Coastal population of sardine-producing communities

The population of sardine-producing communities is about 3.66 percent of the Philippine total population. Identified sardine fishing communities are limited to what was provided by BFAR Regional Offices based on their NSAP sardine production site monitoring. Some information was also obtained from the Philippine Statistical Authority, as well as from the City Agriculture Offices of Las Piñas and Navotas in the NCR. Their assistance, particularly that of the BFAR regional offices, was solicited in the absence of published data on sardine-producing villages. To facilitate identification of sardine-producing communities, a list of coastal villages drawn from http://www.gadm.org and using a Quantum Geographic Information System was provided to BFAR regional field offices, but only a few used it. There might be more villages engaged in the same trade, but this could not be determined due to a lack of government resources and the archipelagic nature of the country. The sardine monitoring by the NSAP is focused on fish yield, and it is possible that not all sardine-fishing communities were identified.

The population density in low elevation coastal zones (LECZ) or coastal areas is 376 persons per km^2 (ArcDev, 2004 in BFAR, 2005). The United Nations Statistical Division defines LECZ as the contiguous area along the coast that is less than 10 metres above sea level. As such, a total of 4 251 coastal *barangays* (village or suburb) out of a total of 41 992 in the national database are identified as highly exposed to coastal river flooding (Cruz *et al.*, 2017). Accordingly, the proportion of the Philippine population that lives in LECZs, including sardine-producing communities, is 17.7 percent as of 2000 (United Nations, 2009).

A total of 117 out of the 1 904 *barangays* in the Zamboanga Peninsula or Region 9 are flood-prone with 74 468 families at risk (NEDA Region IX, 2017). NEDA Region IX (2017) also claimed that Region 9 ranks second in terms of the largest land area most vulnerable to a 1 m rise in sea level since 40 of its 67 municipalities are highly susceptible to submergence based on the PAGASA study. A 1 m rise in sea level is projected to inundate 3 781.89 ha in Zamboanga Del Sur; 3 274.02 ha in Zamboanga Sibugay; and 1 057.05 ha in Zamboanga Del Norte. Region 9 is a major producer of sardine in the Republic of the Philippines.

For a major part of their livelihood the coastal communities depend on the resource whose distribution and productivity are influenced by climate variation (Jacinto *et al.*, 2015). Fishers often experienced damage to their fishing craft, gear and other fishing paraphernalia as well as siltation of fishing grounds and critical habitats i.e. sea grass, coral reef (Nieves *et al.*, 2009). Being an archipelagic country, most of the coastal communities do not have sea walls to protect their homes from storm surge, sea level rise, and soil erosion. Houses are mostly built using lightweight materials that will not withstand strong winds and big waves. The combined effects of extreme events expose coastal communities to higher levels of threat to life and property (PAGASA, 2011). The growing population will add pressure to already fragile fishery resources. While fishers' income is often higher than farmers, earnings are very uncertain, often seasonal, and unevenly distributed within the sector. Allison *et al*. (2009) also noted that fishing livelihoods may be profitable but fishing is a risky trade.

Apart from uncertainties, extreme events also trigger public health issues, including malnutrition among coastal dwellers, particularly in children under five, pregnant women and new mothers (WHO, 2016 in UNESCAP, 2016). For instance, the typhoon Koppu, which made landfall in central Luzon in October 2015, raised the threat of disease outbreaks, such as leptospirosis and dengue.

Some communities have demonstrated the ability to come together to protect their main source of livelihood. Brillo *et al*., (2016) noted that Sindangan, Leon B. Postigo, Jose Dalman, Salug and Manukan municipalities in Zamboanga del Norte were adhering to certain rules to safeguard their resource base even prior to the imposition of the closed season. These communities were observing a three-day fishing ban each month for all fish species in municipal waters, following the lunar phase of every new moon. Likewise, the In-glass Sardine Association (ISDA) leaders, together with BFAR in Zamboanga del Norte, were also floating the idea of having a few months' fishing ban during the sardine spawning period in Northern Zamboanga Peninsula. ISDA is an association of sardine bottlers in Zamboanga del Norte. These actions signify that a co-management arrangement is possible in resource-dependent communities, and this could be built up to incorporate strategies to adapt to climate change challenges. Jacinto *et al*., (2016) found, however, that the sardine sector has a low adaptive capacity due to a lack of awareness and lack of information regarding climate change. These findings corroborate that of Taguiam and Quiambao-Marquez (2016), who invoked the need for an education and information campaign in Zambales to enhance environmental awareness, awareness of climate change (sea level rise) and readiness for any eventuality.

Marine ecosystem services

Coral reefs

Coral reefs cover less than 1 percent of the ocean but contain more than 25 percent of all marine species and millions of people depend on them for their livelihood (Moberg and Folke, 1999 in O'Brien *et al*., 2016). Southeast Asia is home to more than half of the world's coral reefs, with the Republic of the Philippines second only to the Republic of Indonesia in terms of biodiversity, with more than 500 species of reef-building corals and 2 500 marine fish species (San Diego- McGlone, 2015; Javier, 2018). Coral reefs provide shelter and substrate for smaller organisms, as well as food sources for larger epibenthic and pelagic organisms. Aside from providing food, livelihood (fishing and tourism) and recreation for a growing population, coral reefs also serve as buffers during storm surges and sea level rise (Wilkinson *et al*., 1999).

Less than 5 percent of Philippine reefs, however, are in excellent condition due to overfishing, destructive fishing, sedimentation, coastal development and marine-based pollution, among other things (Burke *et al*., 2012 in San Diego-McGlone, 2015). Destructive fishing practices and the negative impact from land-based activities have destroyed 70 percent of fisheries within 15 km^2 of the shore (BFAR, 2005).Coral reefs are also vulnerable to climate change, according to the IPPC, because of sensitivity to thermal stress and CO_2-induced ocean acidification (Parry, *et al.*, 2007). Capili *et al.*, 2005 as cited in Damatac and Santos (2016), found that coral mortality due to bleaching resulted in a 46 percent reduction of live coral cover in the country. To mitigate further anthropogenic threats and conserve the biodiversity of coral reefs, the Republic of the Philippines invested in marine protected areas (MPAs). There are about 1 800 MPAs in the country with information vital for coastal resource management contained in a data base (Cabral *et al.*, 2014). MPAs are either locally or nationally managed, particularly those included in the National Integrated Protected Areas System, which is administered by the Department of Environment and Natural Resources (DENR). Marine sanctuaries in Moalboal and Cebu, are renowned for sardine school runs and are examples of successful MPAs in the country (Mega Global, 2019).

MPAs alone cannot protect coral reef ecosystems against ocean acidification, unless global cooperation and action are taken to decrease carbon emissions. Nonetheless, there are studies being conducted in the Republic of the Philippines to observe and help address ocean acidification issues in the region (San Diego-McGlone, 2017). Among the studies undertaken are coral restoration in reef ecosystems through transplantation, coral sexual propagation, coral juvenile outplantation, and capacity building activities. Technologies are also being developed to improve restoration and management techniques to support coral restoration and rehabilitation (San Diego-McGlone, 2015).

Mangroves

Mangroves provide tremendous value and benefits to humankind and other marine organisms (Garcia, Malabrigo, Gevaña, 2014). Mangroves form nursery habitats and are a source of valuable plant products used as food, traditional herbal medicine and other wood and forest products. Primavera and Esteban (2008) claimed that more than half of the country's 1 500 towns and 42 000 villages depend on these marine habitats for food, livelihood and shelter. Mangrove forests also serve as buffers against winds, waves and storm surges in coastal communities and as efficient traps of sediment from coastal erosion, protection against inundation, and have carbon sequestration potential (Camacho *et al.*, 2011 in Garcia, Malabrigo, Gevaña, 2014).

Mangrove cover in the country, however, declined by 43 percent between 1918 and 2000 due to coastal development, conversion for aquaculture and clearing for firewood (Conservation International Philippines, 2019). A total of 18 000 ha of mangrove forest was damaged during typhoon Haiyan (FAO, 2015a). Protecting and rehabilitating mangroves is one of the most efficient ways to increase climate change resilience. Primavera and Esteban (2008) noted that mangrove planting in the Republic of the Philippines started as community initiatives between the 1930s and 1950s, but became government-sponsored projects in the 1970s, and large-scale international development assistance programmes from the 1980s. However, rehabilitation efforts over the last two decades have revealed low long-term survival of 10 to 20 percent due to the use of inappropriate species and poor site selection (Primavera and Esteban, 2008). Mangroves (*Rhizophora*) are planted in areas that are not its natural habitat, particularly in lower intertidal to subtidal zones where mangroves do not thrive. Recent mapping and monitoring assessment also recorded a decrease in the total mangrove area of about 10.5 percent from 1990 to 2010 (Long *et al.*, 2014 in Cruz *et al.*,2017). Remaining mangrove areas are among the most vulnerable to climate change, particularly mangroves occupying low-relief islands and carbonate settings, and have low sediment supply rates and available upland space (Alongi, 2002 in Cruz *et.al*, 2017). This will affect fish spawning and nursery grounds.

Mangroves are vital to climate change mitigation and adaptation. To maximize their capacity, Duncan *et al.*, (2016) suggested the return of low-intertidal and abandoned fishponds to mangrove greenbelts as they had a good rehabilitation status. The study also found that large rehabilitated fishponds have a larger potential to sequester carbon and protect the coastline. Science-based protocols should be followed in planting mangroves.

3.3.3 VULNERABILITY

This report has adapted the IPPC (2014) definition of vulnerability in Oppenheimer *et al.*, (2014) as "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt."

The vulnerability of 1 007 communities associated with sardine fisheries in 16 regions of the Republic of the Philippines was measured based on fishing dependency (engagement and reliance) as well as on social vulnerability. The indices were patterned after Jepson and Colburn (2013), and Colburn *et al.*, (2016) with some modifications (Table 3.8). Data was gathered from various sources (Annex 3.4) and analysed using principal component and factor analysis like Jepson and Colburn (2013).

TABLE 3.8
Selected fishing dependence and social vulnerability factors

Fishing dependency	
Fishing engagement	**Fishing reliance**
Value of sardine landings	Value of sardine landings by local population
Number of registered commercial boats for small pelagics	Number of registered commercial boats per local population
Number of sardine canneries with sardine landings	Number of sardine canneries with sardine landings by local population
Tonnes of sardine landings	Percent in forestry, farming and fishing occupation
Social vulnerability	
Local population composition	**Poverty Index**
Average household (HH) size	Percent receiving assistance (4Ps)
Percent in poverty	Percent of families below poverty level
Percent 60 and over	
Percent under 15	
Housing characteristics	**Labour force structure***
Percent owning house and lot	Percent female employed*
Percent of houses made of light materials	Percent population in labour force*

Social vulnerability	
Housing characteristics	**Labour force structure***
Percent of HH using own community faucet water system for household cooking	Percent self-employed*
Percent of household using bottled water as main source for drinking	Percent receiving social security**

* Dropped from analyses since only regional data are available.
** No available data.

Source: modified from Jepson and Colburn, 2013; Colburn *et al*., 2016.

For fishing dependency, only Indian sardine production data was considered in the analyses. This fish species is canned in the Republic of the Philippines. In instances where the PSA provided Indian sardine provincial production data, but BFAR did not have data on associated fishing communities, new fishing communities were added, based on what can be extracted from the literature.

Results of the analyses should be used with caution, however, due to some limitations. One or more sample-based census supplementary modules, which would collect in-depth structural data on fisheries, among others, were supposed to be conducted during the 2012 Census of Agriculture and Fisheries but due to the incorporation of former statistical agencies into the PSA by virtue of RA 10625, these were not carried out (PSA, 2017b).

Accordingly, some variables were not considered in the analyses, such as those under the labour structure category. This is because for some variables only regional data was available. Likewise, provincial or municipal data was used in the absence of village data to ensure harmony in data sets within each index.

Fishing dependence

According to Colburn *et al*., (2016), commercial engagement and reliance are two different aspects of the concept of fishing dependence. Others include variables that identify critical infrastructure and people who are involved in fishing within the community. The commercial fishing engagement fishing index is an absolute measure of commercial fishing in the community. The commercial fishing reliance index is a relative measure of commercial fishing within the community based on its population size.

A radar graph was used to plot the fishing engagement and reliance indices factor scores to visualize the interrelatedness of each index and to compare the regions comprising a set of sardine-producing communities. A blue circular line on each index chart represents the threshold of one standard deviation above the mean. Scores outside the threshold circle indicate that the community is experiencing vulnerabilities on a particular index. Fishing engagement and reliance indices can be found in Annex 3.5.

Figure 3.4 shows the community dependence on sardines. Only Region 9 is significantly engaged and reliant on sardine-related activities, indicating the dependence of communities on the commercial sardine fishery and that its supporting industries play a significant role in the local economy. NCR communities rely on fishing for a living. Region 9 is highly engaged in sardine fishing, as indicated by a high index of 3.57. However, the region does not seem to show as much reliance (1.18) on the sardine industry, as indicated by an index of 1.18 which is barely higher than the threshold. These indices imply that while the commercial sardine fishery and its supporting industries in Region 9 play a significant role in the local economy, there are other industries that contribute significantly. For NCR, the fishing engagement index (0.78) almost reaches the threshold, while giving the highest index (2.96) for reliance. This indicates that while not much commercial sardine fishing activity occurs in NCR, the communities rely heavily on the sardine fisheries.

These findings imply that any fishery management action could affect the commercial fishing operation in Region 9 and will also greatly impact the economy and fishing communities in NCR. It is important to involve the stakeholders in decision-making during the formulation of fisheries management regulations to ensure cooperation.

FIGURE 3.4

Commercial fishing engagement and reliance indices of communities

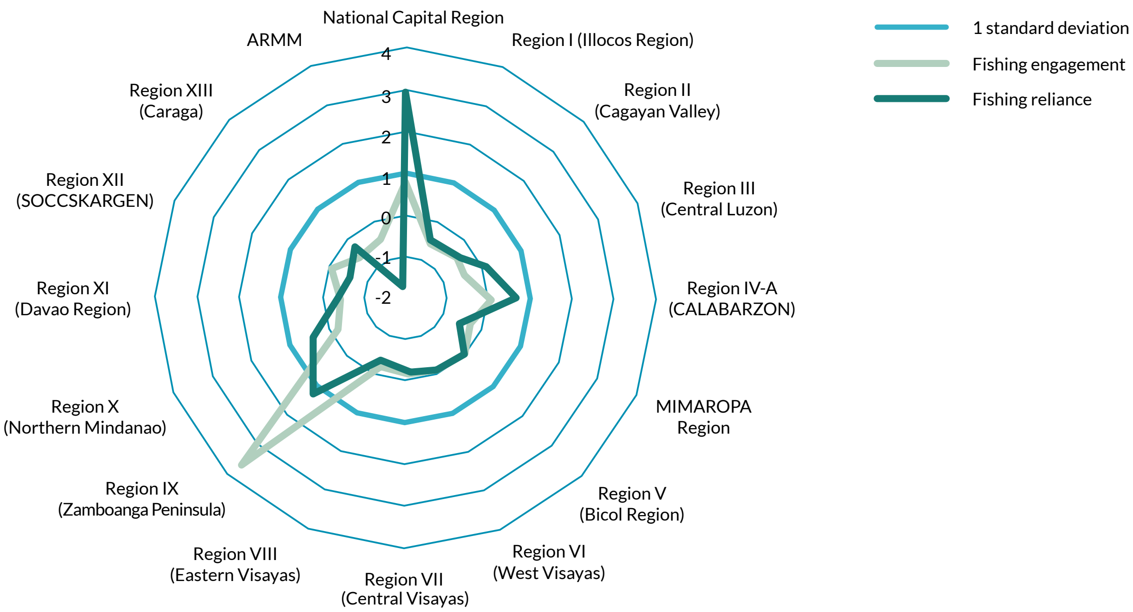


Table 3.9 shows the data summary from the above radar graph using a dichotomous scale of 1 and 0 for a selected group of indices. A score of 1 is given to a community if each factor score for a particular index is at or above one standard deviation above the mean, and 0 if below. Scores for fishing dependence were added together, and a sum of 2 signifies dependence and reliance of the community on commercial fishing engagement.

TABLE 3.9

Sum of fishing dependence indices: commercial fishing engagement and reliance dichotomous scale

Region	Fishing engagement	Fishing reliance	Total fishing sum
NCR	0	1	1
Region 1 (Ilocos Region)	0	0	0
Region 2 (Cagayan Valley)	0	0	0
Region 3 (Central Luzon)	0	0	0

Region	Fishing engagement	Fishing reliance	Total fishing sum
Region 4-A (Calabarzon)	0	0	0
Region 4-B (Mimaropa)	0	0	0
Region 5 (Bicol Region)	0	0	0
Region 6 (Western Visayas)	0	0	0
Region 7 (Central Visayas)	0	0	0
Region 8 (Eastern Visayas)	0	0	0
Region 9 (Zamboanga Peninsula)	1	1	2
Region 10 (Northern Mindanao)	0	0	0
Region 11 (Davao Region)	0	0	0
Region 12 (Soccsksargen)	0	0	0
Region 13 (Caraga)	0	0	0
ARMM	0	0	0

Social vulnerability

As shown in Table 3.8, only three indices of social vulnerability were analysed. The local population composition index includes variables associated with population dependency and quality of life. High factor scores signify a high level of vulnerability for this index.

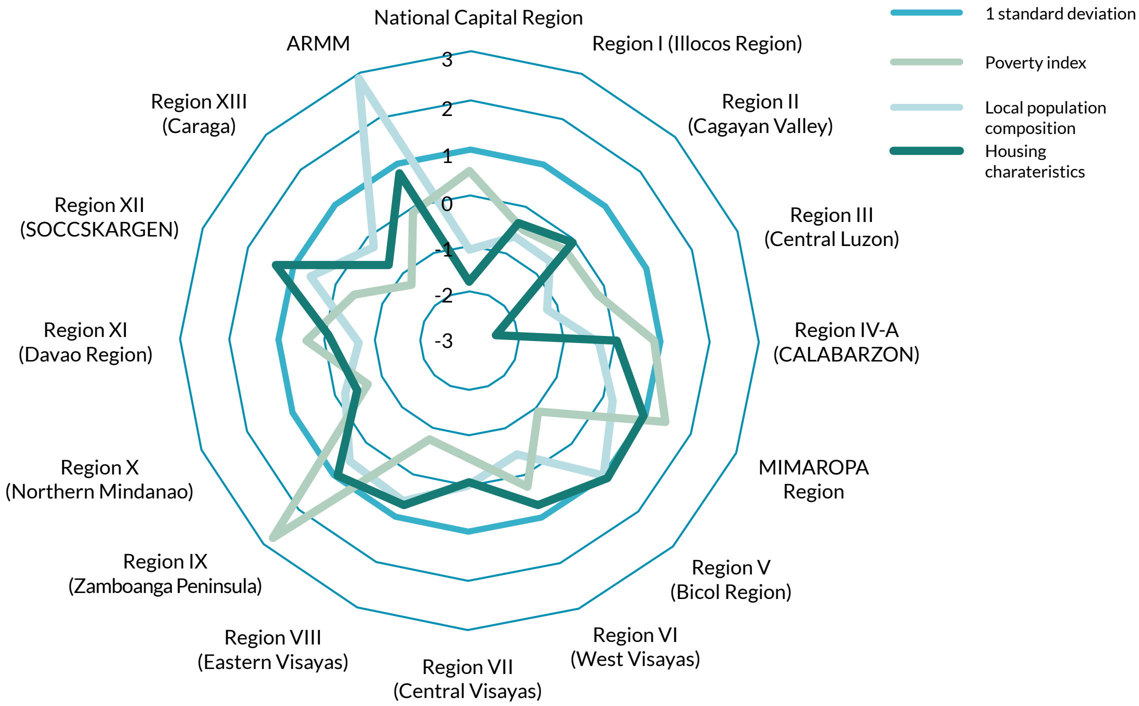
The poverty index incorporates families living in poverty and families receiving assistance from the 4Ps, a government programme that regularly provides conditional cash grants to the poorest of the poor to keep children healthy and in school. Household beneficiaries are selected from Listahan, also known as the National Household Targeting System for Poverty, which covers all poor households with children between birth and18 years old. Pregnant women are also eligible for the programme. High factor scores also imply a high level of vulnerability.

The housing characteristics index covers variables that are indicative of the general housing and living conditions of the community. Factor scores in two variables (owning house and lot and drinking bottled water) were reversed in this category so the index has one common directional tendency. High factor scores mean a high level of vulnerability for this index.

Social vulnerability indices were placed in a radar graph, similar to fishing dependence as shown in Figure 3.5. Regions with two indices above the threshold are socially vulnerable and may have difficulty in rebounding from any local economic disruption due to fishery management regulation. The social vulnerability indices can be found in Annex 3.6.

Results reveal that no region has two indices above the threshold. Region 12 (2.37) shows high scores in housing characteristics, indicating poor living conditions, and thus are vulnerable in this category. Region 4-B (1.30) and Region 9 (2.70) score high on the poverty indices denoting that a high percentage of the population engaged in sardine production or related activities in these regions is poor, and thus vulnerable. ARMM scores high on the local population composition index (2.92) which may be due to a high incidence of poverty, large households or a high dependency in households. This also indicates that these communities are vulnerable in this category.

FIGURE 3.5
Social vulnerability indices of communities



Data in the above graph are summarized in Table 3.10, similar to fishing dependence. Scores of at least 2 of the indices indicate that the community is socially vulnerable and a score of 1 implies community vulnerability on a specific index.

Table 3.10
Sum of social vulnerability indices dichotomous scale

Region	Local population composition	Poverty index	Housing characteristics	Social vulnerability sum
NCR	0	0	0	0
Region 1 (Ilocos Region)	0	0	0	0
Region 2 (Cagayan Valley)	0	0	0	0
Region 3 (Central Luzon)	0	0	0	0
Region 4-A (Calabarzon)	0	0	0	0
Region 4-B (Mimaropa)	0	1	0	1
Region 5 (Bicol Region)	0	0	0	0
Region 6 (Western Visayas)	0	0	0	0
Region 7 (Central Visayas)	0	0	0	0
Region 8 (Eastern Visayas)	0	0	0	0
Region 9 (Zamboanga Peninsula)	0	1	0	1
Region 10 (Northern Mindanao)	0	0	0	0
Region 11 (Davao Region)	0	0	0	0
Region 12 (Soccsksargen)	0	0	1	1
Region 13 (Caraga)	0	0	0	0
ARMM	1	0	0	1

When the analysis was scaled down to provincial level (Annex 3.7), results further revealed important details about vulnerability in the provinces. The results are presented using a dichotomous scale of 1 and 0 for a select group of indices (Annex 3.8). A province receives a 1if the factor score for a particular index is at or over one standard deviation above the mean and 0 if below. A total score of two signifies that the province is socially vulnerable.

Results show that Sulu in ARMM is socially vulnerable, scoring 1 on both local population composition and on housing characteristics. Accordingly, the sardine-producing communitiesin Sulu will have difficulty rebounding from any local economic disruption due to fishery regulations. Provinces that score 1 in only one index are only vulnerable in that specific category. Provinces that score only on housing characteristics are Oriental Mindoro and Palawan in Region 4-B, Masbate in Region 5, Negros Oriental in Region 7 and Davao Oriental in Region 11. Region 12 is also in this category. Meanwhile, the cities of Navotas and Las Piñas in NCR, Zamboanga del Sur and Zamboanga Sibugay in Region 9, and Tawi- tawi in ARMM, obtained 1 score only in the poverty index. Leyte and Northern Samar in Region 8, along with Basilan, Lanao del Sur and Maguindanao in ARMM, scored 1 only in the local population composition.

Overall, sardine-dependent communities in nine out of 16 regions are poor, confirming pervasive poverty among fishers, which undermines their resilience to social-ecological systems. The 2015 survey also corroborates this finding, ranking fishers second (34 percent) to farmers (34.3 percent) in poverty incidence compared to the general population (21.6 percent) (PSA, 2017b). Nieves *et al*., (2009) also found that extreme poverty drove fishers to encroach into the core area of a marine fishery reserve, leading to its destruction. Vulnerability can act as a driver for adaptive resource management, which may vary depending on the nature and level of the community's resource dependency. For instance, Jacinto *et al*., (2016) found that both tuna and sardine sectors are vulnerable to climate change, as assessed using the VA-Tool. The sardine sector, however, showed higher sensitivity because of its high dependency (92 percent) on sardine fisheries and high exposure of fishing grounds to typhoons. This implies that a localized management or adaptive strategy is needed to cope with climate variability (Songcuan and Santos, 2013). These findings emphasize the need for continued examination of the issues of climate change and social vulnerability as subtle differences in coastal communities, their economies and populations may have implications for their ability to adapt to change (Colburn *et al*., 2016). A tool for understanding the resilience of fisheries (VA-TURF) developed by Mamauag *et al*., (2013) will be useful to further understand and assist coastal communities to enhance planning and preparation for climate change impact. Regulatory reforms and collaboration can be attained based on local knowledge, needs, priorities and physical reliabilities (Aldea and Masagca, 2016).

Catch diversity

Fish species caught from 2015 to 2017 in the four fishing grounds in Region 9 varied (Annex 3.9). There were 34 species noted in Illana Bay, 31 in Moro Gulf, and 11 species eachfor Celebes Sea and South Sulu Sea, based on fish landings in one port. The most abundant species in Celebes Sea belong to family *Scombridae* (yellowfin tuna, 51.85 percent; skipjack tuna, 35.12 percent; mackerel tuna, 5.85 percent). Similar trends were observed in the South Sulu Sea (skipjack tuna, 42.81 percent; yellowfin tuna, 35.32 percent). Big-eyed scad (5.34 percent) is also abundant in the latter. In Illana Bay, sardine was most abundant (33.75 percent), followed by skipjack tuna (18.46 percent) and yellowfin tuna (15.49 percent) while in Moro Gulf, skipjack tuna (35.13 percent) was most abundant, followed by yellowfin tuna (27.76 percent); and bullet tuna (10.06 percent). Sardine was only 3.58 percent of the catch from Moro Gulf.

Fishing communities dependent on sardine may struggle to adapt as fish stocks respond to complex changes in ocean temperature, with shifts in species range and productivity (Pinskyand Mantua, 2014 in Colburn *et al.*, 2016). This requires an adaptive response that may include finding new fishing grounds, exploiting different species or seeking non-fishing dependent employment. It must be noted, however, that Region 9 used to be the tuna capitalof the Republic of the Philippines before the industry's collapse in the 1970s. It is not surprising that tuna species dominate some of the fishing grounds based on one port's fish landings.

3.4 GOVERNANCE

Climate change and anthropogenic factors threaten the multiple benefits that fisheries contribute to poverty reduction. They decrease production, damage or destroy physical assets, and affect human health. Development interventions at policy, programme and project levels are needed to reduce uncertainty and ensure long-term commitment to manage resources. A more robust regulatory environment that protects both the fish and the fishers is needed considering there are only a few livelihood alternatives available to fishers (Ferrer, 2016).

3.4.1 CURRENT ADAPTATION ACTIONS

The impacts of extreme events vary between different socio-economic groups, as does the adaptive response to such events. Poor families, for example, seek assistance from relatives for temporary relief and accommodation and look for alternative income like laundering and other forms of domestic work, and relying on government assistance for shoreline protection (Nieves *et al.*, 2009). Some employ "soft" structural reinforcement in their houses and properties, and secure food, water and other necessities, including boats and livestock. However, there are activities that are in place to help coastal communities respond to climatic and non-climatic events (Annex 3.10). These adaptation strategies are organized either by the coastal communities themselves or with assistance from NGOs, national government agencies (NGAs), and LGUs.

3.4.2 EFFECTIVENESS OF CURRENT SARDINE FISHERIES MANAGEMENT AND REGULATIONS

The closed season policy is the only fisheries management measure that the Philippine government has issued specifically for sardine fisheries. The regulation is a globally recognized conservation measure for preserving fisheries resources, particularly by controlling overfishing, protecting the species during spawning season and arresting the dwindling fish catch (Brillo *et al.*, 2016; FAO, 1997 in Narvaez *et al.*, 2018).

The seasonal fishing ban in the Visayan Sea and adjoining waters covering commercial fishing for sardine, mackerel and herring has been in place since 1989 under Fisheries Administrative Order No. 167. BFAR Region 6 reported that observance by fishers of the three-month closed season from 15 November to 15 February every year in the Visayan Sea led to a 20 percent increase in sardine production (Panay News, 2018). A reduction of CVFs operating during the closed season from 349 to 50 vessels was noted, indicating compliance by most CVF operators and effective surveillance. In Region 9, the regulation, which was backed by NSAP scientific data, had a favourable impact on the sardine industry and on commercial and municipal fishers, giving a positive-sum effect to the sardine industry overall (Narvaez *et al.*, 2018; Rola *et al.*, 2018). The institutionalization of a closed season policy under BAC 255 s. 2014 and expanding coverage from 13 987 km^2 to 22 260.36 km^2 in Region 9 is recognition of its biological, ecological and industrial benefits (Campos *et al.*, 2003 in Narvaez *et al.*, 2018; BFAR, 2014). In the Tañon Strait, the CFVs' operations are restricted. The Tañon Strait Protected Seascape is the largest marine protected area in the Republic of the Philippines. It was created under Presidential Proclamation No. 1234 in 1998 (Government of the Republic of the Philippines, 1998b). Despite this, Oceana Philippines (2018) asserted that additional management tools are required to enhance the closed season strategy, such as banning certain fishing gear catching small fish and protecting the areas where sardine spawn, among others.

3.4.3 ADAPTABILITY OF SARDINE FISHERIES GOVERNANCE

Recently, BFAR issued Fisheries Administrative Order 263 dated 28 January 2019, declaring 12 major fishing grounds as fisheries management areas (FMAs) intending to provide a science-based and participatory governance framework. FMAs will institutionalize the regional-based management of major fisheries, including sardine (Oceana, 2018). Fisheries Administrative Order 263 highlights conservation and participatory management in the fisheries sector. It stipulates that a management board will be convened at each FMA to develop its own policies and programmes based on an ecosystems approach. At the same time, local government ordinances will be crafted that will provide a governance framework for sustainable management. All stakeholders will be represented on the management board. It also requires BFAR to convene Scientific Advisory Groups (SAGs) with representatives from academic institutions, BFAR regional offices, municipal fisherfolk groups, the commercial fishing industry and NGOs, to provide technical advice to the management board. The creation of SAGs recognizes the role and importance of science in policy decision-making for managing fisheries.

Prior to Fisheries Administrative Order 263, a National Sardine Management Framework Plan (NSMFP) was launched in March 2017 in partnership with Oceana Philippines to implement a science-based management framework for sardines. The NSMFP seeks to identify concrete steps of action for the next five years to address fisheries, ecological, socio-economics, and governance issues to sustain the country's sardine industry. It is not clear yet whether Fisheries Administrative Order 263 already encompasses the NSMFP.

3.4.4 FLEXIBILITY OF DECISION-MAKING AND PROBLEM SOLVING

With the assistance of NGAs, NGOs and LGUs, various initiatives have been taken to improve the adaptive capacity of the poor. Some are successful, others are not, but there are lessons to be learned from them. Allison *et al.* (2009) proposed, for example, that adaptations in small-scale fisheries must focus on building institutions and rules of management that will increase the capacity of ecosystems and people to accommodate unpredictable change. Flexible and reactive institutions will offer the best chances of minimizing the effects of irreversible change (Allison *et al.*, 2009). As ocean characteristics change, fishing patterns may change, which would have important implications for individuals, fishing businesses and communities. It is this type of complexity that underscores the importance of developing targeted assessment measures that offer the greatest flexibility for management (Colburn *et al.*, 2016). The VA-TURF and FishVool mentioned in Annex 3.10 are important tools that can be used to assess the vulnerability of local fishing communities.

Building consensus through consultation involving major stakeholders, resource users, NGOs and all levels of government (national, provincial and municipal), are important in decision-making and problem-solving processes. The consultation process and involvement of major players are important steps to arrive at consensus on certain issues. The closed season policy in Region 9 was a product of consultation with all stakeholders, particularly the major players in the sardine fishing and processing industry, and was backed by scientific data from NSAP.

Information and education campaigns are essential for public awareness, along with technical and scientific efforts to achieve a well-balanced adaptation plan (Sajise *et al*., 2012). Radio is still the best means of communicating programmes, especially to far-flung areas. An informed population can innovate adaptive techniques to minimize the effect of climate change based on their own vulnerabilities. However, the success of such community initiatives depends on how political establishments and figures, constituents and stakeholders respond to their roles (Aldea and Masagca, 2016).

3.4.5 EXISTENCE OF POWER STRUCTURES

Fisheries in the country are jointly managed by the National Government through the Department of Agriculture–Bureau of Fisheries and Aquatic Resources (DA-BFAR) and the LGUs. The LGUs have jurisdiction over the municipal waters in conjunction with the Fisheries and Aquatic Resources Management Councils (FARMCs) and/or Integrated FARMCs. The DA-BFAR manages all fisheries and aquatic resources other than those in municipal waters. In the face of climate change and other stressors, as the national lead agency, DA-BFAR has to coordinate with and assists LGUs and other government agencies involved in safeguarding, protecting and conserving sardine fisheries, including NGOs and the private sector. The Fisheries Code, however, contains some provisions in which the jurisdictions of DA-BFAR and DENR intersect, particularly the Environmental Management Bureau. As long as there is coordination and sharing of learnings, both can pursue their respective mandates for the common good.

In the face of the many threats to fisheries, both internal and external to the sector, it is perhaps necessary to engage interest groups outside the sector to improve fishery governance (Andrew *et al*., 2007). DA-BFAR, through the FMA, can initiate sectoral consultations to include climate change adaptation plans. Sectoral adaptation options could pose interesting trade-offs for some measures that would be beneficial to some sectors but not to others.

Prioritizing adaptation options should be considered to minimize trade-offs between sectors.

3.5 CONCLUSION AND RECOMMENDATIONS

The socio-economic importance of the sardine fishery to Filipinos cannot be understated. Sardine not only contributes to food security and health, but also provides a substantial livelihood to coastal dwellers, as well as employment in shore-based businesses like canneries and bottling industries, among others. However, climate hazards such as temperature anomalies, ocean acidification, sea level rise and typhoons pose a serious threat to livelihoods, properties, lives and the environment, particularly for people dependent on the resource. While El Niño, for instance, is favourable to the growth and abundance of sardine, it can also inhibit upwelling. Exposure of fishing grounds, productive assets, infrastructure, shore-based sardine-related businesses and coastal communities, including vital marine ecosystems, to climate hazards endangers coastal dwellers' existence, unless mitigation and adaptation to climate change are put in place. The impact of climate hazards will be felt more in socially vulnerable communities dependent on the sardine fishery.

Considering the archipelagic nature of the country, a holistic approach for each community is needed to address fisheries issues and manage the effects of climate change. As discussed earlier in this report, each community has different vulnerabilities. For instance, Region 9 is significantly dependent on commercial fishing and engaging major industry players in sardine fishery policy formulation is vital to avoid disruption of the local economy. In the NCR, sardine fishers are reliant on fisheries, thus, the government's reclamation plan for Manila Bay must be reconsidered, and instead, the bay rehabilitated. Aside from depriving fishers of their livelihood, reclamation poses lethal risks to people due to land subsidence, storm surges and earthquake-induced ground shaking and liquefaction (Rodolfo, 2014). The majority of sardine-dependent communities in the country are also poor and show vulnerability to at least one of the indices for social vulnerability and should be addressed accordingly. For example, communities vulnerable to local population composition imply the need to think about family size to improve family well-being. Thus, programmes related to family planning should form part of the strategy in uplifting community conditions. Poverty is most likely to be exacerbated in these communities, particularly among small-scale fishers, by not addressing the main vulnerability issues, and in light of climate change. The government has addressed poverty in coastal communities through several programmes in the past, like Biyayang Dagat in 1977, but failed, partly because the vulnerabilities of communities were not considered.

Meanwhile, there is apparent competition between and among commercial and municipal fishers in harvesting sardine due to the open access regime. Competition is expected to intensify with an increase in the number of CFVs and in the number of municipal fishers, adding pressure to an already degraded resource. In addition, LGUs may have given CFVs permission to operate within 10.1 to 15 km of municipal waters by virtue of the authority provided for under the 1998 Fisheries Code. There is also a lack of livelihood opportunities available for coastal dwellers. Some fisherfolk have been trained in processing sardine for added income, but high losses in post-harvest activities were noted (Campos and Bagarinao, 2019).

Coastal communities lack awareness of climate change impacts on their lives. Nieves *et al.*, 2009, noted that the government approach to climate change is reactive and more focused on disaster preparedness and mitigation opportunities, instead of providing long-term adaptation programmes to reduce vulnerabilities and improve resource sustainability. Likewise, knowledge and the effects of climate variability and the projected impact of long-term climate change is limited in fisheries (Geronimo, 2018). Finally, institutional partnerships between and among government entities, private organizations and NGOs in managing fishery resources is inadequate. In particular, DA-BFAR must strengthen its coordination aspect with LGUs to ensure commitment from the latter to implement fishing regulations and to provide updated and reliable fisheries data within each LGUs' turf. Given the community vulnerabilities mentioned earlier, it is important to establish an updated and reliable data base of the number and identification of stakeholders, fishing gear, status of resource, and other fishery-related data on fisheries by region, or by FMA. Reliable data is vital in decision-making, be it social, economic, biological or regulatory. Brillo *et al.* (2016) noted the lack of availability of dependable data during the imposition of the closed season in Region 9. There was a disparity of production data between BFAR and the sardine industry which showed an increase in sardine catch in 2012, and the Bureau of Agricultural Statistics (BAS) and PSA which showed a decrease in production. The unexpected decline of sardine commercial catches in the second year of the closed season (2013) was not also fully explained.

In view of the foregoing, co-management should be explored, considering limited government resources, and given the archipelagic nature of the country for implementing fisheries regulations. Involving users and producers in the commercial sector through fishing associations would be an achievement as they could be vital partners in fisheries management. They can help in data collection using their data gathering system and in offshore surveillance. This is not far-fetched considering that some coastal communities in Zamboanga del Norte already adopt rules to protect the resource, and commercial operators practise "self-regulation" to sustain sardine fisheries, as noted by Brillo *et al.* (2016). Geronimo (2018) also found that the greatest climate change impact with respect to the reduction of habitat suitability is felt in offshore waters, rather than coastal waters. Livelihood diversification programmes should also be put in place in coastal communities, and post-harvest practices improved. Commercial and municipal fishers are exposed to climate change hazards and to mitigate a loss of livelihood, they and their families should make use of the training offered by Technical Education and Skills Development Training (TESDA) so they have an alternate livelihood if needed. Along with this, information, education and communication on climate change should form part of the fisheries programmes for coastal communities to build up their resilience. Increased awareness and knowledge on climate change might motivate them to actively participate in the establishment and protection of MPAs and in the rehabilitation and management of mangroves, particularly abandoned fishponds that have no legal impediments because the leases for abandoned ponds have not yet been cancelled (Primavera *et al.*, 2012 in Duncan *et al.*, 2016). An early warning system for incoming typhoons may be necessary for communities frequently visited by typhoons to prevent loss of lives. DA-BFAR must endeavour to strengthen the institutional links, particularly in areas where resources are not substantial, to effectively implement fishery regulations as well as enhance research capabilities on climate change aspects affecting fisheries.

The establishment of FMAs is timely because they use an ecosystems approach that considers both the welfare of the resource and the resource users. FMAs recognize the importance of science and the value of active community participation in the decision-making process, without which programmes are bound to fail. Climate change can also be incorporated into FMA plans and strategies. As Willete *et al.* (2011) aptly put it, the effects of climate change must be factored in to maintain sustainable sardine stocks without ignoring the naturally occurring short and long-term environmental variability.

Adaption of the proposed NSMFP under an FMA can be the initial step to address fisheries issues, taking into account the vulnerability of communities based on the findings of this paper. The FMA Management Board will not be working empty-handed. There are numerous data and tools that can be used, including lessons from the existing Protective Area Management Board and coastal resource management (CRM) experiences, as well as FAO guidelines on sustainable small-scale fisheries (FAO, 2015b). Strengthening of institutions and proper coordination among actors is needed to balance production and conservation.

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ANNEX 3.1 – Type of sardine processors in the Republic of the Philippines by region

Region	Type	Name of company	Address	Source
NCR	Canning	A. Tung Chingco Manufacturing Corporation	#8 Lamco Avenue Lawang Bato, Valenzuela City	https://www.bfar.da.gov.ph/BFAR_EU?id=186
		Akian Food Processing Corporation	Road E1 Avenue, Navotas Fishport Complex NBBS, Navotas City	https://www.bfar.da.gov.ph/BFAR_EU?id=186
		Chattrade Enterprises	822 Elcano Street, 1006 Manila	http://tradelinephilippines.dti.gov.ph/web/tradeline-portal/directories
		Happy Chef, Incorporated	Navotas Fish Port Complex Wharfside Navotas, Metro Manila	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		Maunlad Canning Corporation	631 Elcano Street, Binondo, Manila	http://www.youngstown.com.ph
		Slord Development Corp.	PFDA Fishport Complex, Navotas, Metro Manila	http://www.slord.com.ph/
	Bottling	Gustazo Alimentos Corporation	No. 27 12Th Avenue Cubao, Quezon City	http://tradelinephilippines.dti.gov.ph/web/tradeline-portal/directories
		Kai-Anya Food Inc.	Premier Port Corner St., Banerahan, Navotas Fishport, Navotas	http://tradelinephilippines.dti.gov.ph/web/tradeline-portal/directories
4A	Canning	Century Canning Corp.	Dasmariñas, Cavite	http://tradelinephilippines.dti.gov.ph /web/tradeline-portal/directories
	Others (frozen, dried, salted, smoked)	Caraga Seabounty Co. Ltd.	Building A, Philexport, First Cavite Industrial Estate (FCIE) Admin Complex	http://tradelinephilippines.dti.gov.ph/web/tradeline-portal/directories
		Global Food Solutions, Inc.	Brgy. San Nicolas, San Pablo City, Laguna	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		Green Harvest Food Products	Brgy. Sta. Monica, San Pablo City, Laguna	https://www.bfar.da.gov.ph/BFAR_EU?id=185
6	Canning	Asia Pacific Aqua Marine, Inc.	Panitan, Capiz	http://www.apami.com.ph/
		Victorias Foods Corp.	VMC Compound, J.J. Ossorio St. Barangay XVI, Victorias City Negros Occidental	http://www.victoriasmilling.com
	Others (frozen, dried, salted, smoked)	HLS Aqua Products	Hiccor Compound, Araneta Street. Singcang, Bacolod City	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		New Wave Exporters Inc.	Block 2 Lot 12 Gardenville, Tangub Bacolod City, Negros Occidental	https://www.bfar.da.gov.ph/BFAR_EU?id=185
9	Canning	Aquatic Food Manufacturing Corporation	Brgy. Recodo, Zamboanga City, Zamboanga del Sur	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		Atlantic Food Corporation	Talisayan, Zamboanga City, Zamboanga del Sur	https://doi.org/10.3233/AJW-180002
		Ayala Seafoods Corporation	Calle Segundo, Ayala, Zamboanga City, 7000, Zamboanga Del Sur, Zamboanga, Zamboanga del Sur	https://www.bfar.da.gov.ph/BFAR_ EU?id=185

Region	Type	Name of company	Address	Source
9	Canning	Bigfish Foods Corporation	Barangay Recodo, Zamboanga, Zamboanga Sibugay	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		Century Pacific Food, Incorporated	Dumagsa, Talisayan, Zamboanga City	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		Fortune Group Corporation	Purok 8 Road, Zamboanga City, Zamboanga Del Sur	https://doi.org/10.3233/AJW-180002
		Goldstar Seafood	Dumagsa, Talisayan, Zamboanga City	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		Mega Fishing Corporation	Recodo, Barangay Cawit, Zamboanga, Zamboanga del Sur	https://doi.org/10.3233/AJW-180002
		Permex Producers & Exporters Corporation	Ayala Industrial Estate Zamboanga City	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		Seacoast Top Choice Food Corporation	Sangali Road, Zamboanga City,Zamboanga Del Sur	https://doi.org/10.3233/AJW-180002
		Southwest Asian Canning Corporation	Purok 1, Zamboanga, 7000 Zamboanga del Sur	https://doi.org/10.3233/AJW-180002
		Universal Canning Inc.	Calle San Isidro, Ayala Zamboanga City	https://www.bfar.da.gov.ph/BFAR_EU?id=185
	Bottling	Alenter Food, Incorporated	90 Pescador St. San Antonio Katipunan, Zamboanga del Norte	https://www.bfar.da.gov.ph/BFAR_EU?id=185
		Adriatico Food Products	Zamboanga del Norte	https://doi.org/10.3233/AJW-180002
		Dapitan City Food Products	Lawa-an, Dapitan City, Zamboanga del Norte	https://doi.org/10.3233/AJW-180002
		Dipolog School of Fisheries Food Products	Dipolog School of Fisheries Compound, Olingan, Dipolog City, 7000, Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Dipolog Seaside Women's Association	Fishport, Barra, Dipolog City, Zamboanga Del Norte	https://doi.org/10.3233/AJW-180002
		EJT Food Products	RNR Drive, Zone II, Boalan, Zamboanga City	https://doi.org/10.3233/AJW-180002
		Etch Kiu Products, Inc.	Bolicon, Turno, Dipolog City, 7100, Zamboanga del Norte	https://doi.org/10.3233/AJW-180002
		Fuentes Food Manufacturing	Zamboanga del Norte	https://doi.org/10.3233/AJW-180002
		Gaso Food Products	Junction Polo-Dapitan Park National Rd, Dapitan City, Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Inglass Sardines of Dipolog Association	Polo, Dapitan City, Zamboanga del Norte	https://doi.org/10.3233/AJW-180002
		Jose Dalman Sardines Savers Association	Jose Dalman, Zamboanga del Norte	https://doi.org/10.3233/AJW-180002
		Manukan Sardines Savers Association	Manukan, Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002

Region	Type	Name of company	Address	Source
9	Bottling	Mendoza Industries	National Highway, Dipolog City, 7100 Zamboanga del Norte	https://doi.org/10.3233/AJW-180002
		MM Cadag Food Products	Lot 15, Block 43, Victoria Country Homes, Obay, Polanco, Zamboanga Del Norte	https://doi.org/10.3233/AJW- 180002
		Monina's Sardines	Martinez St, Village, Dipolog City,Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Montaño Foods Corporation	Dapitan City, Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Palandok Agrarian Reform Beneficiaries and Agricultural Multi-Purpose Cooperative (PARBFAMCO)	National Road, Palandok, Leon Postigo, 7113 Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Roxas Sardines Livelihood Association	Dohinob, Pres. Manuel A. Roxas, Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Sindangan Spanish Style Sardines Producers Cooperative	Rizal Street, Barangay Bantayan, Sindangan, 7112, Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Tita Rosa Food Products	027 F.B., Lacaya Street, Dipolog City, 7100, Zamboanga del Norte, Dipolog City, Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Tito Mike's Food Company, Inc.	Airport Rd, Hicayat, Dipolog City, 7100 Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
		Zaragoza Foods Corporation	Dipolog City, Zamboanga del Norte	https://doi.org/10.3233/AJW- 180002
10	Bottling	Food and Fish Processors Association	Ardent Hibok-hibok Spring Resort, Esperanza, Tagdo, Mambajao, Camiguin	BFAR Region 10 (M. Casinillo, pers. comm. 3 March 2019)
		Rural Improvement Club of Cagayanon Association (RICCA)	Cagay-anon, Sinacaban, MisamisOccidental	BFAR Region 10 C M. Casinillo, pers. comm. 3 March 2019)
		Rural Improvement Club of Colupan Bajo (RICCOL)	Colupan Bajo, Sinacaban, Misamis Occidental	BFAR Region 10 C M. Casinillo, pers. comm. 3 March 2019)
		Nagkahiusang Mangingisda Alang sa Kalamboan sa SND (NAMANGKA) Inc	P1 Pigkalawag, SND, Lanao Del Norte	BFAR Region 10 C M. Casinillo, pers. comm. 3 March 2019)
		Kauswagan Fish Processors Association	Poblacion, Kauswagan, Lanao Del Norte	BFAR Region 10 C M. Casinillo, pers. comm. 3 March 2019)
		Kimaya People's Multi-Purpose Cooperative	Kimaya, Jasaan, Misamis Oriental	BFAR Region 10 C M. Casinillo, pers. comm. 3 March 2019)
		La Doña Española Sardi	F.M. Paclar St., Patag, CDOC Misamis Oriental	BFAR Region 10 C M. Casinillo, pers. comm. 3 March 2019)
		Klasik Livelihood Cooperative	Indahag, CDOC, Misamis Oriental	BFAR Region 10 C M. Casinillo, pers. comm. 3 March 2019)

ANNEX 3.2 – Number of workers employed in various fishery and fishery-related establishments in the Republic of the Philippines, by gender

Category		Number of firms	Number of workers per firm*	Male	Female	Total
1.	**Fishing firms** (all employment sizes)					
	Commercial fishing**	206	61	11 601	1 003	12 604
	Coastal fishing**	63	21	1 150	144	1 294
	Subtotal	**269**		**12 751**	**1 147**	**13 898**
2.	**Other firms** (all employment sizes)					
	Canning/packing of fish and other marine products**	53	228	5 386	6 694	12 079
	Drying of fish and other marine products**	57	13	385	329	714
	Smoking of fish and other marine products	22	15	200	130	330
	Processing, preserving and canning of fish, crustacean and mollusc**	61	53	1 239	2 010	3 250
	Building of ships & boats other than sports & pleasure boats**	46	438	NA	NA	20 177
	Repair of ships and boats other than sports & pleasure boats**	38	42	NA	NA	1 587
	Subtotal	**277**		**7 210**	**9 163**	
	Total	**546**				**52 035**

*Estimated average number of workers; **Total may not add up due to rounding.

Source: 2015 Annual Survey of Philippine Business and Industry (PSA, 2017a).

ANNEX 3.3 – Volume and value of sardine production in the Republic of the Philippines by sector, 2013–2017

Year	Volume (in tonnes)			Value (in thousand pesos)		
	Commercial	Municipal	Total	Commercial	Municipal	Total
2013	208 087.47	117 592.26	325 679.73	5 955 897.73	4 043 355.56	**9 999 253.29**
2014	245 226.18	110 837.36	356 063.54	7 063 050.23	3 910 799.62	**10 973 849.85**
2015	261 871.78	118 438.81	380 310.59	7 046 350.09	3 962 635.84	**11 008 985.93**
2016	246 328.83	118 620.47	364 949.30	5 801 462.92	3 879 043.38	**9 680 506.30**
2017	213 253.60	113 712.03	326 965.63	5 640 522.56	3 771 505.04	**9 412 027.60**
Total	**1 174 767.86**	**579 200.93**	**1 753 968.79**	**31 507 283.53**	**19 567 339.44**	**51 074 622.97**
Percent share	67 %	33 %	100 %	62 %	38 %	**100 %**
AAGR	1 %	–1 %	0 %	–1 %	–2 %	**–1 %**

ANNEX 3.4 – Vulnerability variables, sources of data and procedure in obtaining figures for analyses

Category	Source of data	Data collection procedure
Fishing dependence		
Fishing engagement		
Value of sardine landings	http://openstat.psa.gov.ph/ PXWeb/sq/e62c7a7d-eef3-4744-be5d-3e4fbfb4b02f	Absolute figure per region
Number of registered commercial boats for small pelagics	https://www.foi.gov.ph/requests/ aglzfmVmb2k tcGhyHgsSB0Nv bnRlbnQiEUJGQVItNjM5NDgw MDk0MTk5DA	Absolute figure per region
Number of sardine canneries with sardine landings	Various (mostly from BFAR and DTI) sources are listed in Annex 3.1 – Type of sardine processors in the Republic of the Philippines by region	Absolute figure per region
Tonnes of sardine landings	http://openstat.psa.gov.ph/ PXWeb/sq/f35b0f1a-4ca9-497d-98ce-55271364f939	Absolute figure per region
Fishing reliance		
Value of sardine landings by local population	http://openstat.psa.gov.ph/ PXWeb/sq/e62c7a7d-eef3-4744-be5d-3e4fbfb4b02f and Philippine Statistics Authority, 2015 Census of Population	Absolute figure per region multiplied by total local population of sardine-producing communities by region
Number of registered commercial boats per local population	https://www.foi.gov.ph/requests aglzfmVmb2ktcGhyHgsSB0Nv bnRlbnQiEUJGQVItNjM5N & Philippine StatisticsAuthority, 2015 Census of Population	Absolute figure per region multiplied by total local population of sardine-producing communities by region
Number of sardine canneries with sardine landings by local population	Various (mostly from BFAR and DTI); sources are listed in Annex 3.1 – Type of sardine processors in the Republic of the Philippines by region; & Philippine Statistics Authority, 2015 Census of Population	Absolute figure per region multiplied by total local population of sardine-producing communities by region
Percent in forestry, farming and fishing occupation	Table 5 from https://psa.gov.ph/ content/2015- annual-lfs-estimates-tables	Absolute figure per region
Social vulnerability		
Local population composition		
Average household (HH) size	Philippine Statistics Authority, 2015 Population Census	• HH population of sardine-producingcommunities/ Number ofHH per community = HH size per community • Total HH size per community/Number of HH producingcommunities = Average HH size of sardine–producing municipality • Total HH size of sardine-producing municipality/ Number ofHH of sardine-producing municipalities = Average HH size by province producing sardine

Category	Source of data	Data collection procedure
Social vulnerability		
Local population composition		
Percent in poverty (population)	2015 Full-year official poverty statistics of the Republic of the Philippines (Table 2) https://psa.gov.ph/content/poverty-incidence-among-filipinos-registered-216-2015-psa	Absolute figure by province
Percent 60 and over	Philippine Statistics Authority, 2015 Population Census	Absolute figure of population over 60 of sardine-producing communities by province/Total local population of sardine-producing communities by province
Percent under 15	Philippine Statistics Authority, 2015 Population Census	Absolute figure of population under 15 of sardine-producingcommunities by province/Total local population of sardine-producing communities by province
Housing characteristics	http://www.psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Housing%20 Tables%2 0by%20City_%20 Municipality.xlsx	
Percent owning house and lot	http://www.psa.gov.ph/sites/default/files/attach ments/hsd/pressrelease/Housing%20 Tables%20by%20City_%20 Municipality.xlsx	Number of households owning house and lot by municipality with sardine-dependent villages/ Number of total households by municipality
Percent of houses made of lightweight materials	http://www.psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Housing%20 Tables%2 0by%20City_%20 Municipality.xlsx	Total occupied housing units made of lightweight materials by municipality with sardine-dependent villages/Total occupiedhousing units by municipality
Percent of HH using community faucet water system for HH chores	http://www.psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Housing%20 Tables%20by%20City_%20 Municipality.xlsx	HH using community faucet water system for HH chores by municipality with sardine-dependent villages/Occupied housingunits by municipality
Percent of HH using bottled water asmain source of drinking	http://www.psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Housing%20 Tables%20by%20City_%20 Municipality.xlsx	HH using bottled water as main source of drinking by municipality with sardine-dependent villages/ Occupied housingunits by municipality
Poverty index		
Percent receiving assistance (4Ps)	4Ps, Department of Social Welfare and Development	Total population of sardine-producing communities receiving 4Ps by province/ Total population receiving 4Ps by province
Percent of families below poverty level	2015 Full-year official poverty statistics of the Republic of the Philippines (Table 1) https://psa.gov.ph/content/poverty-incidence-among-filipinos-registered-216-2015-psa	Absolute figure by province

ANNEX 3.5 – Fishing engagement and reliance indices

Index variable	Factor loadings	Percentage variance
1) Fishing engagement index		
Value of sardine landings	0.976	
Number of registered commercial boats for small pelagic	0.435	
		75.804
Number of sardine canneries with sardine landings	0.965	
Tonnage of sardine landings	0.979	
2) Fishing reliance index		
Value of sardine landings by local population	0.763	
Number of registered commercial boats per local population	.-0.275	43.557
Number of sardine canneries with sardine landings by local population	0.900	
Percent in forestry, farming and fishing occupation	-0.565	

ANNEX 3.6 – Social vulnerability indices

Index variables	Factor loading	Percentage variance
1) Local population composition		
Percent 60 and over	–0.664	
Percent under 15	0.857	65.803
Percent in poverty	0.834	
Average HH size	0.873	
2) Housing characteristics		
Percent HH owning house and lot	0.620	
Percent houses made of lightweight materials	0.697	
Percent HH using own community faucet watersystem for HH chores	–0.836	57.025
Percent HH using bottled water for drinking	0.843	
3) Poverty index		
Percent receiving assistance (4Ps)	0.796	63.431
Percent of families below poverty line	0.796	

ANNEX 3.7 –Social vulnerability indices at provincial level

Index variables	Factor loading	Percentage variance
1) Local population composition		
Percent 60 and over	0.172	
Percent under 15	0.820	43.609
Percent in poverty	0.819	
Average household size	0.610	
2) Housing characteristics		
Percent HH owning house and lot	0.068	
Percent houses made of lightweight materials	0.824	
Percent HH using own community faucet watersystem for HH chores	–0.771	45.124
Percent HH using bottled water for drinking	0.726	
3) Poverty index		
Percent receiving assistance (4Ps)	0.768	58.994
Percent of families below poverty line	–0.768	

ANNEX 3.8 – Sum of social vulnerability indices at provincial level

Region/Province (number of *barangays*)	Local population composition	Poverty index	Housing characteristics	Social vulnerability sum
NCR				
City of Navotas (10)	0	1	0	1
City of Las Piñas (4)	0	1	0	1
Region 1 (Ilocos Region)				
La Union (3)	0	0	0	0
Pangasinan (2)	0	0	0	0
Region 2 (Cagayan Valley)				
Cavite	0	0	0	0
Region 3 (Central Luzon)				
Bulacan (2)	0	0	0	0
Region 4-A (Calabarzon)				
Batangas (10)	0	0	0	0
Cavite (8)	0	0	0	0
Quezon (22)	0	0	0	0
Region 4-B Mimaropa				
Marinduque (4)	0	0	0	0
Occidental Mindoro (6)	0	0	0	0
Oriental Mindoro (2)	0	0	1	1
Palawan (46)	0	0	1	1
Romblon (4)	0	0	0	0
Region 5 (Bicol Region)				
Albay (4)	0	0	0	0
Camarines Norte (7)	0	0	0	0
Camarines Sur (17)	0	0	0	0
Masbate (5)	0	0	1	1
Region 6 (Western Visayas)				
Aklan (23)	0	0	0	0
Antique (15)	0	0	0	0
Capiz (16)	0	0	0	0
Iloilo (103)	0	0	0	0
Negros Occidental (35)	0	0	0	0
Region 7 (Central Visayas)				
Bohol (4)	0	0	0	0
Cebu (6)	0	0	0	0
Negros Oriental (3)	0	0	1	1

Region/Province (number of *barangays*)	Local population composition	Poverty index	Housing characteristics	Social vulnerability sum
Region 8 (Eastern Visayas)				
Biliran (4)	0	0	0	0
Eastern Samar (8)	0	0	0	0
Leyte (17)	1	0	0	1
Northern Samar (11)	1	0	0	1
Samar (6)	0	0	0	0
Southern Leyte (7)	0	0	0	0
Region 9 (Zamboanga Peninsula)				
Zamboanga del Norte (129)	0	0	0	0
Zamboanga del Sur (132)	0	1	0	1
Zamboanga Sibugay (104)	0	1	0	1
Region10 (Northern Mindanao)				
Camiguin (5)	0	0	0	0
Lanao del Norte (1)	0	0	0	0
Misamis Occidental (4)	0	0	0	0
Misamis Oriental (16)	0	0	0	0
Region 11 (Davao Region)				
Davao del Sur (4)	0	0	0	0
Davao Oriental (1)	0	0	1	1
Region 12 (Soccsksargen)				
Sultan Kudarat (3)	0	0	0	0
South Cotabato (2)	0	0	0	0
Region 13 (Caraga)				
Surigao del Norte (5)	0	0	0	0
Surigao del Sur (3)	0	0	0	0
ARMM				
Basilan (50)	1	0	0	1
Lanao del Sur (15)	1	0	0	1
Maguindanao (30)	1	0	0	1
Sulu (90)	1		1	2
Tawi-tawi (105)	0	1	0	1

ANNEX 3.9 – Species caught in four fishing grounds in Region 9, Republic of the Philippines: San Pedro Port, Pagadian City (2015 to 2017)

Fishing ground name	Scientific name	English name	Local name	Catch (%)
Celebes Sea				
	Auxis rochei	Bullet tuna	*Tulingan*	2.67
	Decapterusmacarellus	Mackerel scad	*Galonggong*	0.28
	Euthynnus affinis	Mackerel tuna	*Kawakawa*	5.85
	Istiophorus platypterus	Indo-Pacificsailfish	*Liplipan*	0.05
	Katsuwonus pelamis	Skipjack tuna	*Budlisan*	35.12
	Makaira indica	Black Marlin	*Malasugi*	0.4
	Makaira mazara	Indo-Pacific bluemarlins	*Malasugi*	0.61
	Selar crumenophthalmus	Big-eyed scad	*Matang-Baka*	0.24
	Thunnus alalunga	Longfin tuna	*Kiyawon*	1.56
	Thunnus albacares	Yellowfin tuna	*Tambakol*	51.85
	Thunnus obesus	Big Eye Tuna	*Barilis*	1.37
Illana Bay				
	Amblygaster sirm	Spotted sardinella	*Tamban*	0.1
	Auxis rochei	Bullet tuna	*Tulingan*	7.8
	Auxis thazard	Bullet mackerel	*Pidlayan*	0
	Canthidermis maculata	Spotted triggerfish	*Kurukur*	0.12
	Carangoides ferdau	Blue kingfish	*Talakitok*	0.02
	Coryphaena hippurus	Common dolphinfish	*Durado*	0.87
	Decapterus kurroides	Cigarfish	*Burot-Burot*	0.35
	Decapterus macarellus	Mackerel scad	*Galonggong*	6.28
	Decapterus macrosoma	Roundscad	*Marot-Galunggong*	8.62
	Decapterus tabl	Roughear scad	*Galunggong*	0.92
	Dussumieria acuta	Hasselt's Sprat	*Balatiyong*	0.01
	Elagatis bipinnulata	Rainbow runner	*Bansikol*	0.94
	Encrasicholina spp.	Anchovy		0.01
	Euthynnus affinis	Mackerel tuna	*Tulingan Puti*	1.64
	Herklotsichthys quadrimaculatus	Bluestripeherring	*Tamban*	0.31
	Istiophorus platypterus	Sailfish	*Liplipan*	0
	Katsuwonus pelamis	Skipjack tuna	*Gulyasan*	18.46
	Makaira nigricans	Atlantic bluemarlin	*Malasugi*	0
	Makaira spp.	Billfish	*Billfish*	0.08
	Mene maculata	Moonfish	*Bilong-Bilong*	0.07

Fishing ground name	Scientific name	English name	Local name	Catch (%)
Illana Bay				
	Rastrelliger brachysoma	Short-bodied mackerel	Agumaa, Buglay, Hasa-Hasa	0.04
	Rastrelliger faughni	Short mackerel	*Hasa-Hasa, Kabayas*	0.38
	Rastrelliger kanagurta	Striped mackerel	*Bulao*	0.11
	Sardinella albella	White sardinella	*Lupoy*	0.08
	Sardinella fimbriata	Sardine	*Tabagak, Lupoy*	0.23
	Sardinella gibbosa	Goldstripe Sardinella	*Awol-Awol*	0.16
	Sardinella lemuru	Bali sardinella	*Tamban*	33.25
	Selar crumenophthalmus	Big-eyed scad	*Matang-Baka*	2.81
	Stolephorus spp	Anchoy	*Balingon*	0.1
	Thunnus alalunga	Longfin tuna	*Kiyawon, Barilis*	0.03
	Thunnus albacares	Yellowfin tuna	*Tulingan*	15.49
	Thunnus obesus	Big-eyed tuna	*Tulingan*	0.66
	Tylosurus crocodilus	Hound needlefish	*Kambabalo*	0.04
	Tylosurus spp.	Needle fish	*Needle fish*	0.01
Moro Gulf				
	Acanthocybium solandri	Wahoo fish	*Tangigi*	0
	Aluterus sp.	Scrawled Filefish	*Sagoksok*	0
	Amblygaster sirm	Spotted sardine	*Tamban*	0.02
	Auxis rochei	Bullet tuna	*Aloy*	10.06
	Auxis thazard	Bullet tuna	*Aloy*	1.23
	Canthidermis maculata	Rough triggerfish	*Tikos*	0.09
	Carangoides ferdau	Bluefin trevally	*Talakitok*	0.12
	Coryphaena hippurus	Common dolphinfish	*Mahi-Mahi*	1.21
	Decapterus kurroides	Red-tail scad	*Marot*	0.19
	Decapterus macarellus	Mackerel scad	*Tamarong*	5.56
	Decapterus macrosoma	Roundscad	*Marot-Galunggong*	0.92
	Elagatis bipinnulata	Rainbow runner	*Bansikol*	1.35
	Encrasicholina sp.	Anchovy	*Anchovy*	0.45
	Euthynnus affinis	Mackerel tuna	*Tulingan Puti*	3.18
	Gempylus serpens	Snake Mackerel	*Mackerel*	0.01
	Istiompax indica	Black Marlin	*Malasugi*	0.03
	Istiophorus platypterus	Sailfish	*Liplipan*	0

Fishing ground name	Scientific name	English name	Local name	Catch (%)
Moro Gulf				
	Katsuwonus pelamis	Skipjack tuna	*Budlisan*	35.13
	Lobotes surinamensis	Tripletail	*Puyo*	0.01
	Makaira indica	Black Marlin	*Malasugi*	0.02
	Makaira mazara	Black spearfish	*Malasugi*	0.24
	Mene maculata	Moonfish	*Bilong-Bilong*	0.01
	Rastrelliger brachysoma	Short-bodied mackerel	*Agumaa, Buglay,Hasa-Hasa*	0.56
	Rastrelliger kanagurta	Stripped Mackerel	*Bulao*	0.01
	Ruvettus pretiosus	Oilfish	*Penahon*	0
	Sardinella lemuru	Bali sardinella	*Tamban*	3.58
	Selar crumenophthalmus	Big-eyed scad	*Matang-Baka*	4.5
	Thunnus alalunga	Longfin tuna	*Kiyawon, Barilis*	0.76
	Thunnus albacares	Yellowfin tuna	*Tulingan*	27.76
	Thunnus obesus	Big-eyed tuna	*Tulingan*	1.66
	Tylosurus crocodilus	Stickfish or Houndfish	*Kambabalo*	1.33
South Sulu Sea				
	Auxis rochei	Bullet tuna	*Tulingan*	1.38
	Auxis thazard	Bullet tuna	*Tulingan*	4.98
	Decapterusmacarellus	Mackerel scad	*Tamarong*	1.45
	Elagatis bipinnulata	Rainbow runner	*Bansikol*	0.67
	Euthynnus affinis	Mackerel tuna	*Tulingan Puti*	4.67
	Istiompax indica	Black Marlin	*Malasugi*	0.43
	Katsuwonus pelamis	Skipjack tuna	Budlisan	42.81
	Makaira mazara	Black spearfish	Malasugi	0.06
	Selar crumenophthalmus	Big-eyed scad	Matang-Baka	5.34
	Thunnus albacares	Yellowfin tuna	Tulingan	35.32
	Thunnus obesus	Big-eyed tuna	Tulingan	2.89

Source: BFAR 9, 2019, unpublished data.

ANNEX 3.10 – Adaptive response to climate and non-climatic processes affecting sardine fisheries in the Republic of the Philippines

Category	Adaptive measure	Source	Issues/recommendation
Dwindling catch	1. Sindangan, Leon B. Postigo, Jose Dalman, Salug and Manukan municipalities in Zamboanga del Norte observed a monthly three-day fishing ban for all fish species in their municipal waters, following the lunar phase of every new moon. 2. Some processors in the canning industry and commercial fishing companies in Zamboanga City have been practicing "self-regulation" by deferring fishing from November to March due to low fish catch	Brillo *et al.*, 2016	Building up their capacities for a co-management arrangement to include climate change adaptive strategies
	Establishment of bay-wide coastal resource management of contiguous municipal waters	Baticados *et al.*, 2004	Uniformity of law adaption for contiguous municipal waters engage in bay-wide CRM
	1. Establishment of MPA and fish sanctuaries involving resource users; MPA (1 800) database with vital information for CRM as a decision support system (DSS), can be seen as a hub to support the fisheries monitoring programme of the BFAR 2. Participation of r esource users as member of Barangay FARMC	Cabral *et al.*, 2014; Aldea *et al.*, 2015; Nieves *et al.*, 2009	Use of database to promote continuity andconnectivity of efforts Fishing ordinance and regulations in overcollection/overfishing is recommended
	Rehabilitation of the degraded areas	Aldea *et al.*, 2015	Close monitoring of rehabilitation progress
	Closed season policy (Visayan Sea; Zam-Pen; Tanon Strait)	BFAR, 1989; BFAR, 2014; PD 1234	Harvest control rules and reference points should have been determined for specific fish species and fishing grounds
	NSAP fish stocks monitoring	Brillo *et al.*, 2016	Use of database (NFRDI database) for decision-making e.g. closed season policy

Category	Adaptive measure	Source	Issues/recommendation
Livelihood strategies	Providing alternate livelihood during closed season; Adaption of eco-friendly livelihood activities that would shift away from resource-degrading livelihood, such as pebble picking	Jacinto *et al.*, 2015; Brillo *et al.*, 2016	Skills training to give community membersoptions that fit their interest and abilities; Make use of TESDA skills training programme
Ocean acidification	Coral restoration in reef ecosystems through transplantation, coral sexual propagation and coral juvenile out plantation, and capacity building activities. Technologies are also being developed to improve restoration and management in support of coral restoration and rehabilitation	MacGlone, 2017	Capacity building
Sea level rise	Mangrove reforestation and rehabilitation in carbon sequestration through reforestation efforts and protection ofmarine waters from encroachment	Primavera and Esteban(2008); Garcia *et al.*, 2014	Observe science-based protocol in plantingmangroves; use of abandoned ponds for mangrove rehabilitation
	Climate forecast that details the probable onset of the event and its likely societal impacts, its magnitude, its duration, and so forth. Governments could identify the level of risk to its food-producing regions by determining if those regions might be at risk of drought or flood or some other climate-related hazard. The information dissemination should be presented in plain language and drill exercises may be necessary to equip communities to respond in case of emergencies	PAGASA, 2018b	Useful for LGUs and concerned parties for adaptive and mitigation planning
Seasonal climate change forecast (temperature, rainfall and extreme events)	DOST-PAGASA projections of climate change by region and province	PAGASA, 2011	Use projections for climate change adaptation and disaster risk reduction planning
Vulnerability assessment tools	1. Tool for understanding resilience of fisheries (VA-TURF) 2. Fisheries vulnerability assessment tool (FishVool)	Mamauag *et al.*, 2013 Jacinto *et al.*, 2015	Use to assess the vulnerability of the coastal fisheries ecosystems in the tropics to climate change. Identifies fisheries commodities and areas that are highly vulnerable to climate change

Chapter 4

Projected impacts of climate change on *Sardinella lemuru* in the exclusive economic zone of the Republic of the Philippines and potential responses

Diana Fernandez de la Reguera

Key messages

- Several changes in the marine ecosystems of the Republic of the Philippines are already evident because of the impacts of climate change, and future projections indicate that these changes will be accentuated in the long term and will affect the fisheries and aquaculture sector.

- Under a representative concentration pathway (RCP) 2.6 scenario, with a significant reduction of greenhouse gas (GHG) emissions and a sustained mitigation effort, the projected maximum catch potential of Sardinella lemuru in the EEZ of the Republic of the Philippines is not likely to decrease by 2050, although changes in distribution and size might occur, and the overall projected potential catch of all species combined might decrease.

- Without a strong global response to the threat of climate change, current GHG emission tendencies are heading for a scenario RCP8.5 with high GHG concentrations in the atmosphere. Under these circumstances, the projected maximum catch potential of all species combined in the EEZ of the Republic of the Philippines by 2050 is likely to decrease significantly, with Sardinella lemuru potentially decreasing more than other species.

- To guarantee the sustainability of the Sardinella lemuru fishery in the EEZ of the Republic of the Philippines and considering the different projections on potential catch by mid-century, a flexible management plan is needed that foresees immediate actions, addresses the current state of resources and prepares for future changes (i.e. planning, monitoring, research), as well as medium- to long-term actions to adapt to future changes.

- Anticipating the effects of climate change and taking appropriate action will require a portfolio of adaptation tools and approaches dealing with three main strategies or categories:

    - risk reduction and management;
    - viable livelihoods and strengthening institutions; and
    - capacity building.

4.1 EXPECTED IMPACTS OF CLIMATE CHANGE IN FISHERIES

4.1.1 POTENTIAL CLIMATE CHANGE SCENARIOS AS IDENTIFIED BY THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

There is scientific consensus on the anthropogenic influence of the warming of the climate system and the various changes in earth's climate due to the increase of the GHG emissions into the atmosphere (IPCC, 2014). Climate change has already impacted life on the planet in various unprecedented ways in the last decades to millennia; the mean temperatures of the atmosphere and ocean are increasing, snow and ice sheets are melting, and the sea level is rising. In the next decades, experts predict that these impacts are going to worsen, even if there is a complete cessation of anthropogenic GHG emissions, due to the inertia of the climate system[1] (IPCC, 2014).

The Intergovernmental Panel on Climate Change (IPCC) is the international body of reference for assessing the effects of climate change and its consequences on the environment and society. The IPCC periodically produces technical reports on the latest knowledge on climate change and provides predictions of the effects of climate in the environment and society. To do so, the IPCC has defined a number of possible scenarios, describing future GHG emissions depending on a number of assumptions on future human population, energy sources and management measures. For each scenario, the IPCC provides information on expected climate effects, as well as potential adaptation and mitigation measures available.

According to the Fifth Assessment Report of the IPCC (IPCC, 2014), anthropogenic GHG emissions into the atmosphere have increased significantly, reaching 49±4.5 GtCO2 eq/year[2] in 2010. Global average combined land and ocean surface temperature data, calculated by a linear trend, have shown a warming of 0.8 °C, at a rate of more than 0.1 °C per decade.

The ocean absorbed more than 90 percent of the additional energy generated and about 30 percent of the emitted anthropogenic carbon dioxide (CO_2) between 1971 and 2010 (IPCC, 2014). Even though warming varies in different regions of the ocean, the trend is mostly positive and is more pronounced in the Northern Hemisphere. On average, surface waters (0 m to 700 m deep) warmed globally by 0.7 °C per century from 1900 to 2016 (Huang *et al.*, 2015). This warming has exacerbated a decline in oxygen levels in surface waters and an expansion of tropical oxygen minimum zones in the last decades (IPCC, 2014).

The absorption of anthropogenic CO_2 in the ocean has also decreased pH levels of surface waters by an average of 0.1 units since the beginning of the industrial era (IPCC, 2014). Observed global trends of ocean pH already exceed the range of the natural seasonal variability over most of the oceans (Henson *et al.*, 2017). This decrease in pH results in higher water acidity, which is potentially detrimental for calcifying organisms, although the effects at ecosystem level are still inconclusive (Kroeker, Kordas and Harley, 2017).

[1] According to the contribution of Working Group I to the Fifth Assessment Report of the IPCC, a large fraction of climate change resulting from anthropogenic GHG emissions is irreversible on a long-term scale, except in the case of a large net removal of CO2 from the atmosphere over an extended period of time. In the case of complete cessation of GHG emissions, surface temperatures will remain at elevated levels and, due to the long-time scales of heat transfer from the ocean surface to depth, ocean warming will continue for centuries (IPCC, 2013).

[2] GHG emissions are quantified as CO2-equivalent (GtCO2-eq) emissions using weightings based on the 100-year Global Warming Potentials, and IPCC Second Assessment Report values, unless otherwise stated.

Global mean sea level has risen by 0.19 m from 1901 to 2010. However, the rate of increase has a high variability across regions, with values up to three times higher in the Western Pacific or even null or negative in the Eastern Pacific (IPCC, 2014).
In addition to the above changes, there is already evidence of changes in timing, strength and location of different events related to ocean circulation and coastal upwelling, which is attributed to climate change (Rhein *et al.*, 2013; Bahri, Barange and Moustahfid, 2018).

To predict future changes in climate and its potential effects and assess the vulnerability of earth systems to these changes, the IPCC has developed a number of climate change scenarios. These scenarios use a combination of climate models to simulate future changes, according to different anthropogenic GHG emissions, and are driven by population size, economic activity, lifestyle, energy use, land use patterns, and technology, and also mitigation measures and climate policies adopted (van Vuuren *et al*., 2011).

The different models used generate an array of scenarios or representative concentration pathways (RCPs), which simulate possible future ranges of heat or radiative forcing values at the end of the 21st Century relative to pre-industrial values. The RCPs include one scenario with very high GHG concentration levels and no climate-related policies (RCP8.5); two intermediate scenarios (RCP6.0 and RCP4.5); and one rigorous mitigation scenario with low GHG emissions (RCP2.6). The RCP2.6 is a "peak-and-decline" scenario, as its radiative forcing level first peaks around 3.1 W/m^2 by mid-century and returns to 2.6 W/m^2 by 2100. To reach such radiative forcing levels, GHG emissions have to be reduced significantly over time (van Vuuren *et al*., 2011).

Relative to the average of the 1850 to 1900 period, it is estimated that for all RCP scenarios, except for RCP2.6, global atmospheric temperature change is *likely* to exceed 1.5 °C at the end of the twenty-first Century. It is also *likely* to exceed 2 °C for RCP6.0 and RCP8.5, and *more likely than not* to exceed 2 °C for RCP4.5. Although there will be interannual-to-decadal variability and regional heterogeneity, warming is also forecast to continue beyond 2100 under all RCP scenarios, except for RCP2.6 (IPCC, 2014, see Figure 4.1).

According to *Global Warming of 1.5 °C*, an IPCC special report (IPCC, 2018), there is also high confidence that global warming is likely to reach 1.5 °C between 2030 and 2052 if GHG emissions continue to increase at the current rate.

Depending on the different scenarios, the effects of climate change on the marine environment present substantial and geographically diverse risks and expected impacts on ecosystem services, including fisheries. In general, the expected impacts of climate change include:

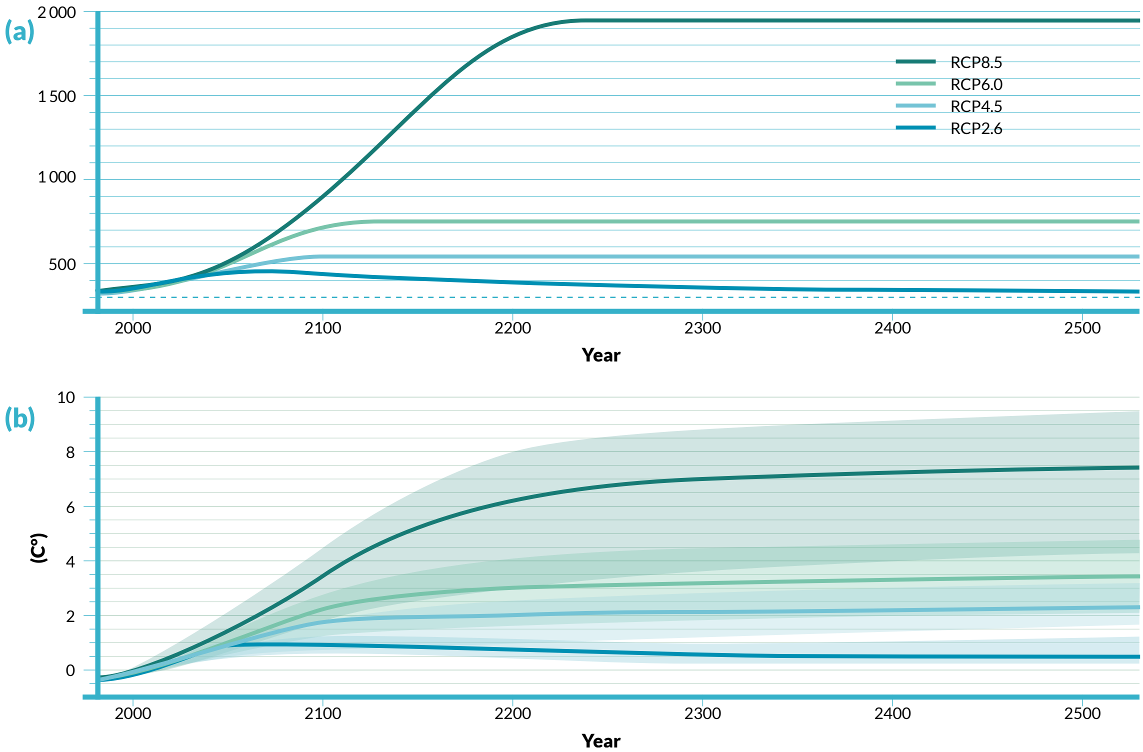
- continued warming of the ocean;
- decreasing oxygen levels;
- decreasing pH levels;
- reduced primary production and migration of species to more suitable habitats;
- modified marine ecosystems; and
- affecting all services provided by the ocean.

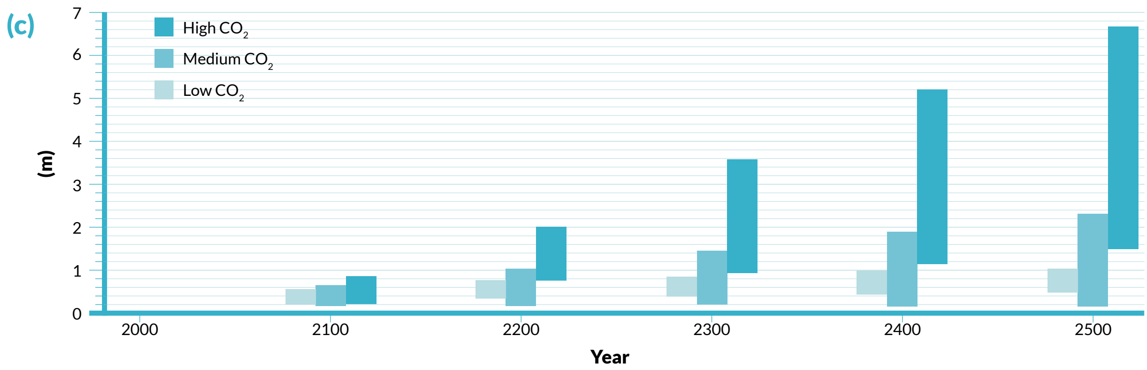
On account of the risks identified, the Paris Agreement of the United Nations Framework Convention on Climate Change (UN, 2015) urges its signatories to take action to keep global temperature rise well below 2 °C above pre-industrial levels this century to avoid significant impacts of climate change (Article 2.1.a of the Paris Agreement). The Paris Agreement is also an integral part of the 2030 Agenda, calling for action to combat climate change and its impacts. It highlights the expected positive effect of climate change actions in support of sustainable development goals (SDGs), in particular SDG 13 (climate action) and 14 (life below water), but also in support of many other SDGs, including the eradication of poverty. It also recognizes the vulnerability of food production systems, including fisheries and aquaculture, to the negative impacts of climate change. This agreement is implemented at country level via nationally determined contributions (NDCs), through which contracting parties report progress on their actions. Over 80 countries have so far included fisheries and aquaculture in their priority adaptation areas and actions (Strohmaier *et al.*, 2016) and the Republic of the Philippines is one of them. Its NDCs include impacts and adaptation to fisheries but also other marine categories such as ocean carbon storage, creation of marine protected areas and impacts on marine ecosystems (Gallo, Victor and Levin, 2017).

The latest findings of the IPCC highlight the need to strengthen the response to climate change to reduce the warming up to 1.5 °C above pre-industrial levels as the negative effects will be significantly less than those caused by a warming of 2 °C or more (IPCC, 2018). In relation to fisheries, Cheung, Reygondeau and Frölicher, 2016, found that limiting the temperature increase to 1.5 °C substantially improved catch potential and decreased turnover of harvested species. These results provide further support for achieving this important goal.

The IPCC also published a special report on climate change and the oceans and cryosphere to further understand the effects of climate change on the marine environment, marine ecosystems and marine resources, including fisheries (IPCC, 2019).

FIGURE 4.1
(a) Atmospheric carbon dioxide CO_2; (b) Surface temperature change (relative to1986–2005; (c) Global mean sea level rise (relative to 1986–2005)





The dashed line indicates the pre-industrial CO_2 concentration) and (b) projected global mean air surface temperature change for the four RCPs up to 2 500 (relative to 1986 to 2005); (c) Sea level change projections according to GHG concentrations (low: below 500 ppm as in RCP2.6; medium: 500 ppm to 700 ppm as in RCP4.5; high: above 700 ppm and below 1 500 ppm as in RCP6.0 and RCP8.5). The bars represent the maximum possible spread.

Source: IPCC (2014).

4.1.2 SIMULATING THE POTENTIAL IMPACTS OF CLIMATE CHANGE IN FISHERIES

Fisheries and aquaculture contribute significantly to the food security and livelihoods of millions of people around the world. According to FAO's *The State of World Fisheries and Aquaculture* (FAO, 2018), total global fish production peaked at 171 million tonnes in 2016 (excluding aquatic mammals, reptiles, seaweeds and other aquatic plants), with capture fisheries representing 53 percent of the total and aquaculture representing 47 percent, reaching 53 percent if non-food uses are excluded. The total value at the first sale of the production of fisheries and aquaculture in 2016 is estimated to have been USD 362 billion, of which USD 232 billion came from aquaculture production (FAO, 2018). Since the late 1980s, the production of capture fisheries has remained relatively constant, while aquaculture has experienced a significant increase and contributed significantly to global fish consumption. Between 1961 and 2016, the rate of increase of fish consumption worldwide (3.2 percent) surpassed population growth (1.6 percent), contributing significantly to global food security (FAO, 2018).

However, according to FAO's assessment of fish stocks, the sustainability of marine fisheries has continued to decline. The fraction of marine fish stocks fished within biologically sustainable levels has exhibited a decreasing trend, from 90 percent in 1974 to 66.9 percent in 2015 (FAO, 2018), with developing countries having worse levels than developed ones (Ye and Gutierrez, 2017).

The source of income and livelihood of many millions of people around the world depends on the fisheries and aquaculture sectors. According to official statistics for 2016, 59.6 million people were engaged in the fisheries and aquaculture primary sector, with 40.3 million in capture fisheries and 19.3 million in aquaculture (Barange and Cochrane, 2018). Around 14 percent of these employed workers were women (FAO, 2018), but this percentage increases to 50 percent if the secondary sector of fisheries and aquaculture is included (Monfort, 2015).

The increase of anthropogenic GHG emissions, as described in the first part of this document, is expected to have consequences for the productivity, seasonality and distribution of fisheries resources and will impact food security in the twenty-first century (Cheung, Reygondeau and Frölicher, 2016, Barange *et al*., 2014). It is also expected that a warmer climate will lead to changes in the frequency, intensity, geographic distribution and timing of extreme events (e.g. marine heatwaves, storms) with subsequent impacts on aquatic systems, livelihoods and productive assets (Poulain and Wabbes, 2018).

The main drivers that will affect the marine biodiversity and fisheries potential worldwide are an increase of global mean ocean surface temperature, acidification, a decrease in oxygen levels and a decrease in primary production (Pörtner *et al.* 2014). However, at regional level the changes will be heterogenous under any scenario, affecting fisheries in different ways, including changes in the distribution of fish species and other taxonomic groups, increasing incidence of coral bleaching with serious implications for dependent ecosystems, and increasing frequency of outbreaks of harmful algal blooms.

FAO's Technical Paper 627 provides projections of the changes in marine maximum catch potential between now and the end of the twenty-first century. The projections are derived from two climate living marine resource models, a dynamic size-based food web model (Blanchard *et al.*, 2012) and a species-based dynamic bioclimate envelope model (DBEM) (Cheung et *al.*, 2016a)[1]. Both models were driven by the same outputs from collections of earth system models from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) and are thus comparable. Projections were made under the lowest (RCP2.6) and highest (RCP8.5) emission scenarios, representing respectively, two extreme scenarios:

- one with rigorous mitigation of GHG emissions with an expected increase of global mean temperatures below 2 °C by the end of the century; and
- the other with high GHG emissions and no climate policy, with an expected increase of global temperature of between 2.6 °C to 4.8 °C by the end of the century (IPCC, 2014).

Application of these two models resulted in projections indicating that the total maximum catch potential of the world's EEZs is likely to decrease by 2.8 percent to 5.3 percent under RCP2.6, and by 7.0 percent to 12.1 percent under RCP8.5 by 2050 (relative to 2000). At the end of the century, the projected decrease does not change significantly under RCP2.6 at a global level, but is likely to be considerably greater – between 16.2 percent to 25.2 percent under RCP8.5. However, there are substantial regional differences and also significant uncertainties in the estimates that need to be taken into account (as provided in the Technical Paper).

Results show the biggest decreases in catch potential in the EEZ in the tropics, mostly in the South Pacific region for all scenarios and timeframes. For high-latitude regions, catch potential is projected to increase, or show less of a decrease than in the tropics, but the two models showed higher variability in the results in that area in general, than those for lower latitudes (Cheung, Bruggeman and Butenschön, 2018). This is consistent with other similar studies (e.g. Lotze *et al.*, 2019).

It should be noted that these projections do not represent potential changes from current catch levels, but rather changes in the capacity of the marine ecosystems to produce fish in the future compared with their current capacity. It is common to assume that climate change impacts future fish catches relative to current levels of catch, directly proportional to changes in the capacity of the ocean to produce fish. However, this would only be the case if production was optimized and continued to be so in the future. It is more appropriate to see

[1] Part 3 has a more detailed description of the methods used for projecting changes for the specific case of the sardine fishery in the Republic of the Philippines, in particular on the DBEM.

changes in the ocean's productive capacity as providing an upper limit to future fish catches. However, whether these catches are an increase or a decrease from present catch levels depends on management decisions now and in the future (Barange, 2019). Management measures and adaptation action/adaptive capacity can contribute to minimize some of the threats and maximize the opportunities emerging from climate change in the fishing communities (Cheung, Bruggeman and Butenschön, 2018; Barange, 2019).

4.2 BRIEF DESCRIPTION OF THE REPUBLIC OF THE PHILIPPINES' MARINE ECOSYSTEM AND FISHERIES

4.2.1 MARINE ECOSYSTEM

The Republic of the Philippines is the world's second largest archipelagic state and a major fishing nation. It consists of more than 7 100 islands with a total land area of 301 000 km^2 (Figure 4.2). In 2017, the population was more than 100 million. The total area of marine waters included within the country's EEZ is 2 200 000 km^2 and the total length of its coastlines is 36 289 km, one of the longest national coastlines in the world. The country's marine continental shelf covers 18.46 million ha and includes an area of coral reef of 2.7 million ha.

It has a tropical climate governed by the monsoon regime. During the southwest monsoon months, the northern and central parts of the region are affected by typhoons, which bring intense rains and destructive winds to coastal areas. The tropical climate, warm waters, ocean currents and upwellings favour the biologically diverse marine environments (Heileman, 2009).

FIGURE 4.2
Ocean base map of the Republic of the Philippines

Source: Esri, General Bathymetric Chart of the Oceans, National Oceanic and Atmospheric Administration, National Geographic, DeLorme, HERE Technologies, GeoNames, and other contributors.

The Republic of the Philippines' marine waters are characterized by a large variety of ecosystems, including mangrove, seagrass, sea mounts and algal ecosystems, a relatively large continental shelf on the western side and a narrow continental shelf that leads to a large deep trench (the Philippines Trench) on the eastern side. The western part of the

Republic of the Philippines' EEZ is included in the Sulu-Celebes Sea Large Marine Ecosystem (LME), while the eastern part, characterized by a small continental shelf and large depths, is included in the Philippine Sea, a marginal sea of the North Pacific Ocean.

The Republic of the Philippines is included in the Coral Triangle, a hotspot of diversity that contains a large number of marine species, including corals, fish and shellfish, marine mammals, reptiles and invertebrates (Asian Development Bank, 2014). The area is well known for its productivity and sustains a large population of fish of a variety of species.

In particular, sardines are abundant fish in coastal waters over the continental shelf (depths less than 200 m) of the Republic of the Philippines, especially in productive coastal areas or upwelling regions. Larger populations are associated with areas of high rates of primary productivity (Willette *et al.*, 2011).

Different species of sardine occur in the Republic of the Philippines, although there is inconsistency in the literature on the exact number (around 9 different species) due to difficulties in the proper identification of species, or changes in the taxonomy of these species (Willette *et al.*, 2011). The Republic of the Philippines has the only known freshwater sardine, endemic to Taal Lake in Batangas. Sardines can be morphologically difficult to differentiate and misidentification of species is common.

The most fished sardine species in the Republic of the Philippines, as per the Bureau of Fisheries and Aquaculture reports, are *Sardinella lemuru* (Indian sardine, misidentified in most statistics as *Sardinella longiceps*, as pointed out by Willette and Santos [2013]) and *Sardinella fimbriata* (Fimbriated sardine; Willette *et al.*, 2011). *Sardinella fimbriata* is also difficult to differentiate from *Sardinella gibbosa*, *Sardinella albella*, and the newly identified species *Sardinella pacifica* (Hata and Motomura, 2019), and therefore a certain level of misreporting is likely.

4.2.2 FISHERIES IN THE REPUBLIC OF THE PHILIPPINES

The Republic of the Philippines is one of the most important fishing countries in the world, ranking as the tenth producer of marine capture fisheries, with a production of more than 1.8 million tonnes in 2016, representing around 2.4 percent of the world's total marine captures (FAO, 2018)[2]. However, this production has decreased in recent years, with a reduction of 13.5 percent according to the average production from 2005 to 2014. The Republic of the Philippines is also the world's eleventh major aquaculture producer (excluding aquatic plans) with 0.8 million tonnes produced in 2016, and the third producer of farmed seaweed, with 1.4 million tonnes produced in 2016 (4.7 percent of the world's production) (FAO, 2018).

The mean per capita consumption of fish and fishery products is around 36.8 kg/year (or 101 grams/day) of which 67.2 percent is consumed fresh (BFAR, 2018). The fish and fishery products consumption compared to the total consumption is 12.8 percent and represents 21.1 percent of the total protein consumption in the country (BFAR, 2018). Other studies based on household survey data show that fish consumption might be even bigger in the Republic of the Philippines and the difference might be due to underestimates of national fish production (Needham and Funge-Smith, 2014). In particular, small pelagic fish species are an important

[2] These statistics are likely to be underestimated because discards, subsistence fishing and gleaning (gathering for local consumption of shellfish, invertebrates or small fishes) are not included (Palomares and Pauly, 2014).

source of protein for the poorest and more vulnerable inhabitants of the country.

The Republic of the Philippines is divided into three main island groups: Luzon, Visayas and Mindanao. These are further divided into 17 regions (16 administrative and 1 autonomous) for administrative purposes (Figure 4.3). As of 2015, region IV – Calabarzon – was the most populated region, while NCR – National Capital Region – was the most densely populated. All the regions have marine capture fisheries, except Cordillera Administrative Region (CAR), the only inland region.

The fishing industry comprises marine capture fisheries, inland capture fisheries and aquaculture, with marine capture fisheries divided into municipal fisheries and commercial fisheries (Government of the Republic of the Philippines, 1998). Municipal marine capture fisheries operate with vessels up to 3 gross tonnage (GT) (or without vessels) in municipal waters (coastal waters within 15 km from the coastline). In 2016, municipal marine capture fisheries represented 22.4 percent of the total capture and 34.5 percent of the total value of the fishing industry (Table 4.1). Commercial marine capture fisheries operate outside municipal waters with vessels of 3 GT or larger, even though local government units may individually allow commercial fishing within 10.1 km to 15 km. In 2016, commercial fisheries represented 23.3 percent of the total capture and 25.7 percent of the total value of the fishing industry (BFAR, 2018).

There are also municipal inland capture fisheries that operate using vessels of 3 GT or less, mainly in lakes, rivers and reservoirs but also estuaries and brackish water fishponds. Aquaculture includes all forms of raising and culturing fish and other aquatic species in fresh, brackish and marine waters (Government of the Republic of the Philippines, 1998).

In 2016, the revenues of the fisheries sector were more than USD 4 800 million, contributing to the country's gross domestic product respectively by 1.3 percent and 1.5 percent at current and constant 2000 prices (Table 4.1). The fisheries sector provides employment to over 1.6 million people nationwide, 85 percent of whom work in municipal fisheries and 1 percent work in commercial fisheries, while the aquaculture sector employs 14 percent (BFAR, 2018).

TABLE 4.1
Total fish production by sector in 2016
Source: BFAR, 2018; PSA, 2018.

Sector	Quantity (tonnes)	Percentage	Value (million USD)	Percentage
Aquaculture	2 200 913	50.5	1 919	39.8
Commercial	1 016 948	23.3	1 240	25.7
Municipal	1 137 931	26.1	1 662	34.5
Marine	976 941	22.4	1 498	31.1
Inland	160 990	3.7	164	3.4
Total	**4 355 792**	**100**	**4 820**	**100**

The volume of exports increased in 2016, reaching more than 250 000 tonnes with a total export value of USD 950 million. The three most exported commodities were tuna, seaweeds and shrimps/prawn, which accounted for 59 percent in volume and 56 percent in value of the total exports. The Republic of the Philippines also imports fish products, with a USD 475 million total import value. Most of the imports are chilled or frozen fish (59 percent), prawn feeds (2.6 percent), as well as flour, meals and pellets of fish, crustaceans and molluscs (2.4 percent) (BFAR, 2018).

FIGURE 4.3
National Stock Assessment Programme map of the Republic of the Philippines with the different regions and municipal water boundary[1]

Source: modified from Santos *et al.* (2017).

[5] Not an official map. Drawing based on the 15 km distance from shoreline as per RA 8550 as amended by RA 10654.

Long-term spatio-temporal trends of the Republic of the Philippines' fisheries production based on the landed national fish catch data from 1980 to 2012 showed that most marine capture fisheries throughout the country either stagnated or decreased over the past three decades. The decrease is most prominent at the regional level. Despite the decrease of fish catch volume, the total Republic of the Philippines' fish catch value has continued to increase over this period. Meanwhile, local municipal fishers are experiencing both low fish catch and income, contributing to observable poverty in many coastal communities (Anticamara and Go, 2016).

According to Briones (2007), even though fish catch has not increased over time, the fishing effort and the number of registered municipal and commercial fishers in the country have increased. Other studies also mention overfishing as a major factor in the declines of catch per unit effort (CPUE), catch biomass, diversity and shifts in fish community structure, observed in Philippine waters (Silvestre *et al.*, 2003; Muallil *et al.*, 2014; San Diego and Fisher, 2014). Aquaculture (mainly seaweeds), rather than marine capture fisheries, has maintained the total production volume of Philippine fisheries since the 2000s. Stagnating capture fisheries in the Republic of the Philippines could be a matter of economic and ecological concern, since low marine fish catch could be an indication of depleted fish stocks (Anticamara and Go, 2016).

Sardine is one of the most fished species in terms of volume, with Indian sardines (*Sardinella lemuru*) and fimbriated sardines (*Sardinella fimbriata)* together representing 24.2 percent of the commercial fisheries captures and 11.4 percent of the marine municipal captures in 2016 (Table 4.2 and 4.3). The value of Indian sardines represents around 3 percent of the total value of the marine production in the Republic of the Philippines (PSA, 2018).

TABLE 4.2
Commercial fisheries production by major captured fish species in 2016

Major species	Total (tonnes)	Percentage
Indian sardines (*Tamban*)	205 986	20.3
Skipjack (*Gulyasan*)	189 612	18.6
Roundscad (*Galunggong*)	156 187	15.4
Frigate tuna (*Tulingan*)	77 098	7.6
Yellowfin tuna (*Tambakol/Bariles*)	67 917	6.7
Big-eyed scad (*Matang-baka*)	46 240	4.5
Fimbriated sardines (*Tunsoy*)	39 343	3.9
Indian mackerel (*Alumahan*)	23 933	2.4
Eastern little tuna (*Bonito*)	21 227	2.1
Slipmouth (*Sapsap*)	14 901	1.5
Indo-pacific mackerel (*Hasa-hasa*)	13 471	1.3
Other species	16 033	15.8
Total	**1 016 948**	**100**

Source: BFAR, 2018.

TABLE 4.3
Marine municipal fish catch by major captured fish species in 2016

Major species	Total (tonnes)	Percentage
Indian sardines (*Tamban*)	74 487	7.6
Big-eyed scad (*Matang-baka*)	66 587	6.8
Frigate tuna (*Tulingan*)	56 789	5.8
Roundscad (*Galunggong*)	55 589	5.7
Squid (*Pusit*)	40 174	4.1
Indian mackerel (*Alumahan*)	39 387	4.0
Fimbriated sardines (*Tunsoy*)	37 243	3.8
Anchovies (*Dilis*)	37 240	3.8
Yellowfin tuna (*Tambakol*)	35 120	3.6
Slipmouth (*Sapsap*)	33 722	3.5
Other species	500 604	51.2
Total	**976 941**	**100**

Source: BFAR, 2018.

TABLE 4.4
Commercial and marine municipal captures by region in 2016

Region	Commercial (tonnes)	Municipal (tonnes)	Total per region (tonnes)	Percentage of Sardine
NCR – National Capital Region	115 416	7 574	122 990	24.9
I – Ilocos Region	4 111	22 571	26 682	0.5
II – Cagayan Valley	10 881	20 895	31 775	4.5
III – Central Luzon	4 890	27 682	32 573	7.2
IV-A – Calabarzon	52 995	36 213	89 208	15.6
IV-B – Mimaropa Region	35 585	129 649	165 235	8.3
V – Bicol Region	59 655	119 485	179 139	17.7
VI – Western Visayas	73 318	130 602	203 920	10.6
VII – Central Visayas	30 454	55 337	85 791	9.8
VIII – Eastern Visayas	24 613	82 753	107 366	8.6
IX – Zamboanga Peninsula	222 536	124 275	346 811	49.5
X – Northern Mindanao	39 038	41 658	80 695	30.1
XI – Davao Region	5 562	23 007	28 569	8.8
XII – Soccsksargen	242 020	15 221	257 241	0.6
XIII – Caraga	5 173	51 748	56 921	10.7
ARMM – Autonomous Region in Muslim Mindanao	90 703	88 272	178 975	10.0
Total	**1 016 948**	**976 941**	**1 993 889**	**17.9**

Source: PSA, 2018.

TABLE 4.5
Volume of Indian and fimbriated sardine captures by region in 2016

Region	Indian sardines (tonnes)	Fimbriated sardines (tonnes)	Total sardine per region (tonnes)
NCR – National Capital Region	29 087	1 512	30 600
I – Ilocos Region	96	48	144
II – Cagayan Valley	802	634	1 436
III – Central Luzon	908	1 448	2 356
IV-A – Calabarzon	9 113	4 814	13 927
IV-B – Mimaropa Region	9 199	4 489	13 688
V – Bicol Region	9 432	22 312	31 744
VI – Western Visayas	10 026	11 670	21 696
VII – Central Visayas	4 063	4 335	8 398
VIII – Eastern Visayas	5 382	3 816	9 198
IX – Zamboanga Peninsula	160 405	11 139	171 543
X – Northern Mindanao	20 876	3 433	24 309
XI – Davao Region	2 215	297	2 512
XII – Soccsksargen	1 107	464	1 571
XIII – Caraga	4 501	1 565	6 066
ARMM – Autonomous Region in Muslim Mindanao	13 261	4 610	17 870
Total	**280 473**	**76 586**	**357 058**

Source: PSA, 2018.

The regions with a higher percentage of sardine in total landings in 2016 were region IX or Zamboanga Peninsula with 49.5 percent, region X – Northern Mindanao with 30.1 percent and NCR – National Capital Region with 24.9 percent (Table 4.4). Catches of sardine are mainly from two groups, Indian sardines and fimbriated sardines, and in terms of volume, the largest catches of these groups in 2016 were IX – Zamboanga Peninsula, V – Bicol Region, and NCR (Table 4.5).

Zamboanga Peninsula is dominated by small pelagic fish and the major fishing grounds around the peninsula are mainly sardine fishing areas. In fact, nine of the top ten species of the region are small pelagic fish with *Sardinella lemuru* making up around 50 percent of the total volume (PSA, 2018). The dominance of *Sardinella lemuru*, or "*Tamban*" is attributed to the seasonal upwelling in the northern part of Zamboanga, driven by the northeast Monsoon (Santos, Barut and Bayate, 2017). Zamboanga City and Dipolog City are the main canned sardine processors and bottled sardine processors, respectively. The sardine industries in Zamboanga Peninsula comprise 12 canning factories, 25 active bottled sardine processors, ten allied fish processors, four tin can manufacturers, 20 commercial fishing operators, 2 046 licensed municipal fishers and 588 licensed vessels, with the majority of fishing gear designed to catch sardine. The sardine industries employ about 35 000 workers per year (Narvaez *et al*., 2018).

In 2011, owing to a sudden decrease in sardine catches in the region from 2009, the Department of Agriculture and the Department of the Interior and Local Government enforced a three-month fishing ban in Zamboanga Peninsula, as a mitigative measure to conserve the sardine species and sustain the operations of its industries. This was an extension of similar conservation measures implemented in other regions (Narvaez *et al.*, 2018). The closure resulted in an increase in the landed catch of sardine and other high value species, which benefitted the incomes of the fishing crews. Even though factory wages declined during the closed season, working hours and days increased during the open season and the overall impact on society was positive (Rola *et al.*, 2018). Other regions have implemented similar fishing bans for sardine and other species to help fisheries to recover. Research was also done on predictive approaches to provide information and monitor the status quo of target species and their habitat.

Fisheries resources and marine ecosystems in the Republic of the Philippines face different impacts due to habitat destruction, overfishing and destructive fishing practices (e.g. dynamite and cyanide fishing on reefs), pollution, etc. According to the One Shared Ocean project[3], around 27 percent of the stocks have collapsed or been overexploited in the Sulu-Celebes Sea LME, while the majority of the landings come from maximally sustainably fished stocks (almost 70 percent). In addition, modelled estimates of floating plastic debris (both microplastic and macroplastic) indicate a high plastic concentration due to shipping density, coastal population density and level of urbanization within major watersheds. Including previously projected potential effects of climate change (see part III and IV), the Sulu-Celebes Sea LME has a high cumulative human impact (score 4.25; maximum LME score is 5.22) and is also believed to be vulnerable to climate change due to the stressors related to ocean acidification, UV radiation and sea surface temperature. Other stressors contributing to this high cumulative human impact are destructive demersal commercial fishing; non-destructive high-bycatch demersal fishing; commercial shipping; sea level rise; ocean-based pollution; pelagic low-bycatch commercial fishing; and demersal non-destructive, low-bycatch commercial fishing.

4.2.3 OVERALL EXPECTED IMPACTS OF CLIMATE CHANGE IN THE REPUBLIC OF THE PHILIPPINES' MARINE ECOSYSTEMS

Several changes in the marine ecosystems of the Republic of the Philippines related to climate change are already evident and are expected to increase in the following decades.

The annual mean surface air temperature in the Republic of the Philippines has increased by 0.68 °C (from 1951 to 2015), which is equivalent to a 0.1 °C increase per decade. From projections in the IPCC scenarios, it is expected that by mid-century the temperature could increase by 0.9 to 1.9 °C with RCP4.5 (moderate emissions scenario) or 1.2 °C to 2.3 °C with RCP8.5 (high emissions scenario) (PAGASA, 2018).

Surface sea water in the Republic of the Philippines has been warming at an average of 0.2 °C per decade since 1982, with an average absolute increase of 0.65 °C in 2017 based on NOAA's Optimum Interpolation SST using a Theil-Sen estimator. The warming is not homogeneous; offshore areas are warming at a faster rate (e.g. Pacific Ocean, waters off Antique and Ticao) while others are warming slower than average (e.g. western Luzon, Sulu Archipelago, Moro Gulf, etc.) (Geronimo, 2018). Projections of the Earth system models from the CMIP5 on mean sea surface temperature increase by 2100 range from 0.3 °C to 3.1 °C depending on the emissions scenario.

[3] www.onesharedocean.org

In terms of rainfall, increasing trends in annual and seasonal rainfall due to extreme rainfall events are being observed in many parts of the country. However, those changes vary significantly spatially and seasonally (related to monsoon and wet season). According to multi-model projections for RCP8.5, a 40 percent range of increase and decrease of seasonal mean temperature from historical values might occur, even though these changes might be due to natural rainfall variations, except for the drier projections for Mindanao region (PAGASA, 2018).

In relation to tropical cyclones (TCs), there was a slight decline in the number and a small increase in the frequency of very strong TCs (exceeding 170 km/h) between 1951 and 2015 and it is expected that these trends will continue in the future (PAGASA, 2018). This is in agreement with the projections of the IPCC, where the average annual number of TCs in the western North Pacific is expected to decrease and it is more likely than not that the frequency of strong TCs will increase (IPCC, 2013).

So far, the mean sea level in some regions of the Republic of the Philippines rose 5.7 mm/year to 7.0 mm/year between 1993 and 2015; nearly double that of the global mean sea level rise of 2.8 mm/year to 3.6 mm/year between 1993 and 2010. This difference could be related to natural climate events such as El Niño Southern Oscillation, which directly affects the tropical Pacific region. The increase of sea level might worsen the impacts of storm surge in coastal areas. It is projected that the sea level in the Republic of the Philippines will increase by around 20 cm by the end of the century under the high emissions scenario (RCP8.5) (PAGASA, 2018).

CMIP5 models in the Republic of the Philippines also show a decrease in Chlorophyll-a and primary production (0.5 percent to 11.8 percent of current averaged values), a decrease in dissolved oxygen and a decline of pH values. In terms of marine biodiversity, global models also predict relatively high risks of marine species extinction and a low risk of species invasion (Cheung *et al.*, 2009).

4.3 DESCRIPTION OF THE EXPECTED IMPACTS ON THE CATCH POTENTIAL OF SARDINE OFF THE REPUBLIC OF THE PHILIPPINES UNDER CONTRASTING SCENARIOS

4.3.1 METHODOLOGY USED

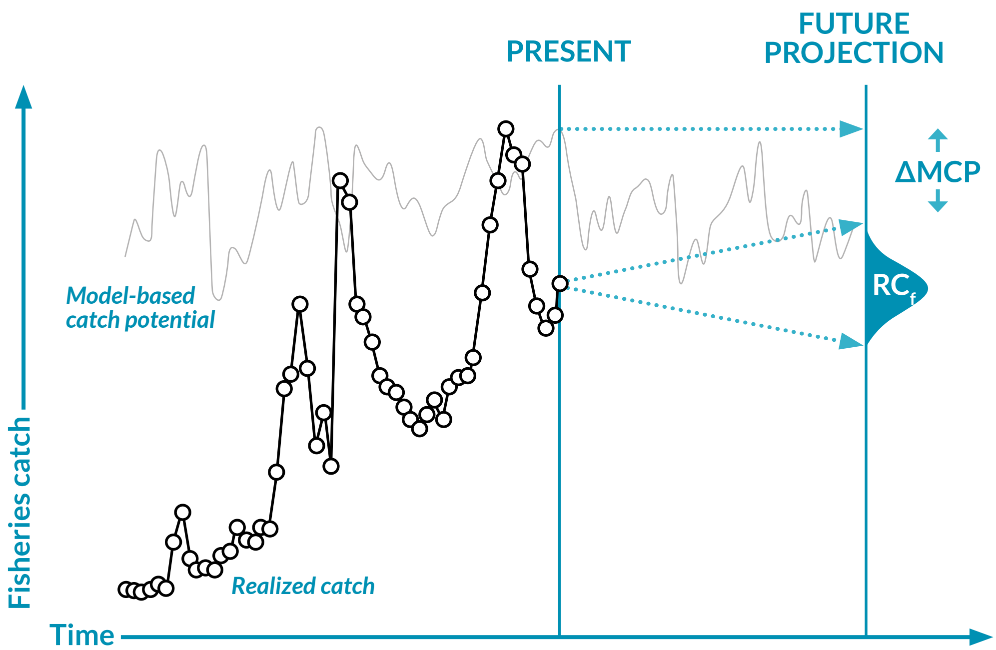
The methodology used to describe expected impacts of climate change in the Republic of the Philippines' fisheries is the one described in Chapter 4 of FAO Technical Report 627 (Cheung, Bruggeman and Butenschön, 2018), based on previous works from Cheung, Reygondeau and Frölicher, (2016) and Cheung *et al.* (2009, 2011, 2016a, b). In short, the method is based on describing changes in maximum catch potential, either for the Republic of the Philippines' fisheries in general or for sardine (*Sardinella lemuru)*, under a number of possible climate change scenarios, using a DBEM. The DBEM is composed of different models, including an Earth system model, and a living marine resources model with an integrated fishing model, which are summarized below.

Variability in the predictions is incorporated through the use of different Earth system models (see below), and projections of future maximum catch potential are provided to 2050 (as the average of the 2046 to 2055 predictions) and 2100 (as the average of the 2091 to 2100 predictions). A summarized description of the different model components is included below, and further details of the methodology are described in Cheung *et al.*, 2016a (supplementary material).

Maximum catch potential

The maximum catch potential (MCP) is the maximum catch that can be extracted from the resources without affecting their future sustainability. It is a substitute for the maximum sustainable yield (MSY), a well-established criteria for managing fisheries. MCP is different to realized catch (RC) (Figure 4.4), which is the actual catch obtained from the fishery using a given fishing pressure, which may not be equal to the pressure required to obtain MSY. In fisheries management, it is assumed that if the realized catch is larger than MSY for a sufficiently long period, the resource will not be able to replenish itself and could be depleted.

FIGURE 4.4
Conceptual representation of model-based MCP over time (grey line), leading to ΔMCP between a point in time in the future and the "present" year



RC (black line with annual markers) and envelope rather than point-estimate of RC in the future (RCf). RCf should not be seen as present catch reduced by ΔMCP, but rather an envelope upper-bounded by future MCP, increasing towards it if adaptive management measures are set in place, and away from it otherwise.

Source: from Barange, 2019.

Earth system models used

Three different models simulating the most relevant aspects of the Earth (Earth system models), available as part of the fifth phase of the CMIP5 within the framework of the IPCC, were used for the projections:

- Geophysical Fluid Dynamic Laboratory Earth System Model 2G (GFDL SM 2G) ;
- Institute Pierre-Simon Laplave Climate Model (IPSL-CM5A-MR); and
- Max Planck Institute Earth System Model (MPI-ESM-MR).

These Earth system models were run (one single realization) from 1850 to 2005 under historical forcing, and from 2006 to 2100 under the IPCC scenarios RCP2.6 (low emissions and strong mitigation measures) and RCP8.5 (business-as-usual). Predictions for the model were done at a 0.5 ° latitude x 0.5 ° longitude grid, when needed by a bilinear interpolation method. The Earth system models' outputs used for the living resource model described below include:

• sea water temperature (surface and bottom);
• hydrogen ion concentration (surface and bottom);
• oxygen concentration (surface and bottom);
• salinity (surface and bottom);
• net primary production (depth integrated); and
• sea ice extent and surface advection.

Living marine resources model

Living marine resources models forecast the changes of the dynamics of marine ecosystems under different ocean conditions projected in the Earth system models. The different ocean conditions generate changes in physiological processes like respiration and growth, and/or the ecological processes of primary production, habitat sustainability and consumption.

For the analysis done in this document, one of the two models used in Chapter 4 of FAO Technical Paper 627 – a species-based DBEM – was used (Cheung, Bruggeman and Butenschön, 2018; Cheung, Reygondeau and Frölicher, 2016; Cheung *et al.*, 2016a). This model uses existing knowledge on the habitat and current distribution of either *Sardinella lemuru* or a number of species considered for the Republic of the Philippines, as well as models of the growth and reproductive potential of those species in relation to the outputs of the Earth system model and tries to infer the future abundance and distribution of the species. The pertinent aspects of the DBEM model are summarized below:

Current species distribution

The current distribution of commercially exploited species, including *Sardinella lemuru*, based on an average pattern of relative abundance from 1970 to 2000, was produced by an algorithm developed by the Sea Around Us[6]. This algorithm predicts the relative abundance according to the species' preference of depth range, latitudinal range, and occurrence regions according to known FAO statistical areas and polygons. The species distribution was further refined through observed habitat preferences such as preference for inner or outer shelf, estuaries, coral reef habitats, etc. The existing habitat preference by species were obtained from FishBase[7] and SeaLifeBase[8], but these distributions have not been validated in situ.

Prediction of future habitat suitability

Based on the current distribution and the existing environmental variables found in the current habitat for any given species, a model of habitat suitability/preference was developed. The habitat is defined by variables such as seawater temperature, salinity, depth, distance from sea-ice and habitat type (coral reefs, estuaries, seamounts and other habitats). These models allow us to predict future habitat preference using the outcomes of the Earth system models.

[6] http://www.seaaroundus.org
[7] www.fishbase.org
[8] www.sealifebase.org

Modelling population growth

In any particular location, individual growth (in weight) is modelled as a function of oceanographic variables (temperature, oxygen content and pH), allowing us to incorporate changes in the metabolisms as well as the potential effect of stress induced by changes in water acidity.

Population growth is modelled with a logistic function, where population changes depend on changes to natural mortality and reproduction, both obtained from available empirical observations.

Ecosystem carrying capacity

Carrying capacity in each cell is assumed to be a function of the unfished biomass of the population, the habitat suitability and net primary production. For the assumed logistic growth function, the unfished population is a function of the population growth and MSY, which is estimated as the average of the top ten annual catches by weight from 1950 to 2010, for each of the species included in the model. The initial carrying capacity at each location is estimated as the unfished biomass times the habitat suitability, and the changes to carrying capacity with time are made proportional to changes in the habitat suitability and net primary production.

Modelling dispersal and movement of larvae and juveniles/adults

Movement and dispersal of adults and larvae were modelled through advection–diffusion–reaction equations. Pelagic larvae were assumed to be passively advected and diffused through ocean currents and related mixing. The duration of the larvae phase was predicted from an empirical equation as a function of sea surface temperature. Colonization of new habitats (species invasion) was a result of either dispersal of larvae or movement of adults to the new habitat. For juvenile-adult stages, diffusion rate was dependent on habitat suitability and a function of the carrying capacity, abundance and mean weight. A gradient of diffusion rate between neighbouring cells resulted in net movement from less to more suitable habitats or from more crowded to less densely populated areas.

Prediction of changes in biomass in space

The model simulated changes in relative abundance and biomass of a species based on changes in population carrying capacity, intrinsic population growth, and the advection–diffusion of the adults and larvae of the population, driven by ocean conditions projected by the Earth system models. The projections of species turnover and changes in fish distribution are driven by changes in temperature, oxygen levels, net primary production, salinity and other ocean conditions.

Fishing model

A constant fishing mortality rate across the geographic range of each species is applied. To predict maximum potential catches, mortality rate is assumed as the mortality that produces MSY. As a logistic growth is assumed, the fishing mortality to achieve MSY is assumed as half the intrinsic rate of population increase.

4.3.2 RESULTS

Projected changes in total maximum catch potential of the sardine species *Sardinella lemuru* within the EEZ of the Republic of the Philippines by 2050 and 2095 (relative to catch potential in 2000) and under RCP2.6 and RCP8.5, were calculated with the DBEM model (Table 4.6). Specifically, maximum catch potential of *Sardinella lemuru* was projected to decrease on average by 0.2 percent to 3.8 percent under RCP2.6 by 2050 and 2095, respectively.

Contrarily, the decrease was larger under RCP8.5 – 27.3 percent to 83.3 percent by 2050 and 2095, respectively. However, the different Earth system models used to drive the projections provide variable results (see Table 4.6), making the average changes under RCP2.6 to be not significantly different than zero. For the scenario RCP8.5, the range of projections is also very large, but the negative changes are significantly different from zero, reaching a maximum negative change of up to 53.4 percent by 2050.

According to Cheung, Bruggeman and Butenschön (2018), maximum catch potential of all species combined of the EEZ of the Republic of the Philippines is likely to decrease on average by 8.3 percent to 9.3 percent under RCP2.6, and by 23.3 to 23.7 percent under RCP8.5 by 2050, according to the projections of the DBEM model and the dynamic size-based food web model. At the end of the century, the total maximum catch potential is likely to decrease by 5.0 percent to 11.2 percent under RCP2.6, and by 42.2 percent to 59.2 percent under RCP8.5 (Table 4.6, Figures 4.5 and 4.6). Again, when considering the variability of the projections, average changes by mid-century under RCP2.6 are relatively small, but significant for scenario RCP8.5.

In all the projections and scenarios used, the average change to maximum catch potential in the Republic of the Philippines is also larger than the average change worldwide (Cheung, Bruggeman and Butenschön, 2018).

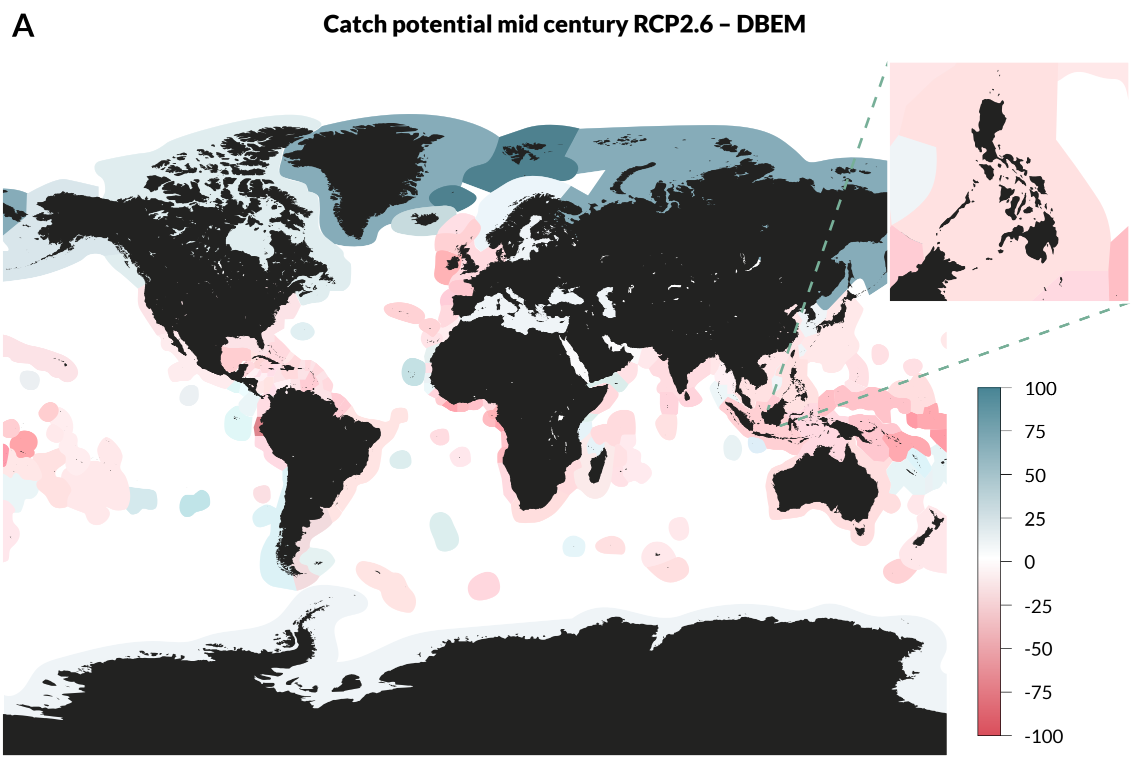
TABLE 4.6
Projected changes (percent) in catch potential in the world, and in the case of the Republic of the Philippines, for all species combined and for *Sardinella lemuru* by 2050 and 2095 (relative to 2000) under RCP2.5 and RCP8.5 based on the results of the DBEM

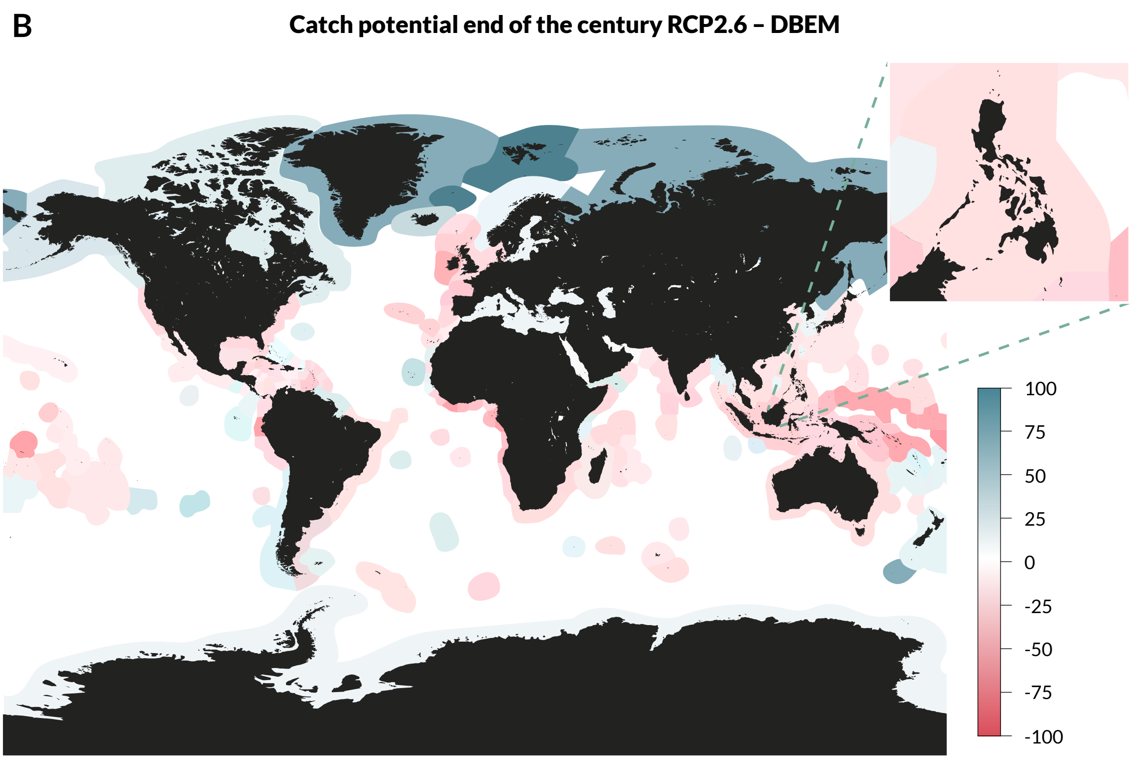
Time frame	RCP2.6				RCP8.5			
	Mid-century		End of the century		Mid-century		End of the century	
	Average	Range	Average	Range	Average	Range	Average	Range
Global catch potential (all species)	−2.8	–	−2.8	–	−7	–	−16.2	–
Republic of the Philippines catch potential (all species)	−8.3	19.6	−11.2	15.3	−23.7	35.2	−59.2	25.7
Republic of the Philippines catch potential (*Sardinella lemuru*)	−0.2	16	−3.8	19.9	−27.3	52.2	−83.3	26.7

The table shows the average change in catch potential per EEZ as well as its range (difference between the minimum and maximum estimate from the different climate models used to drive the projections).

FIGURE 4.5

DBEM projected changes in maximum catch potential (percent) under RCP2.6 A: by mid-century (2046 to 2055); and B: by the end of the century (2091 to 2100)

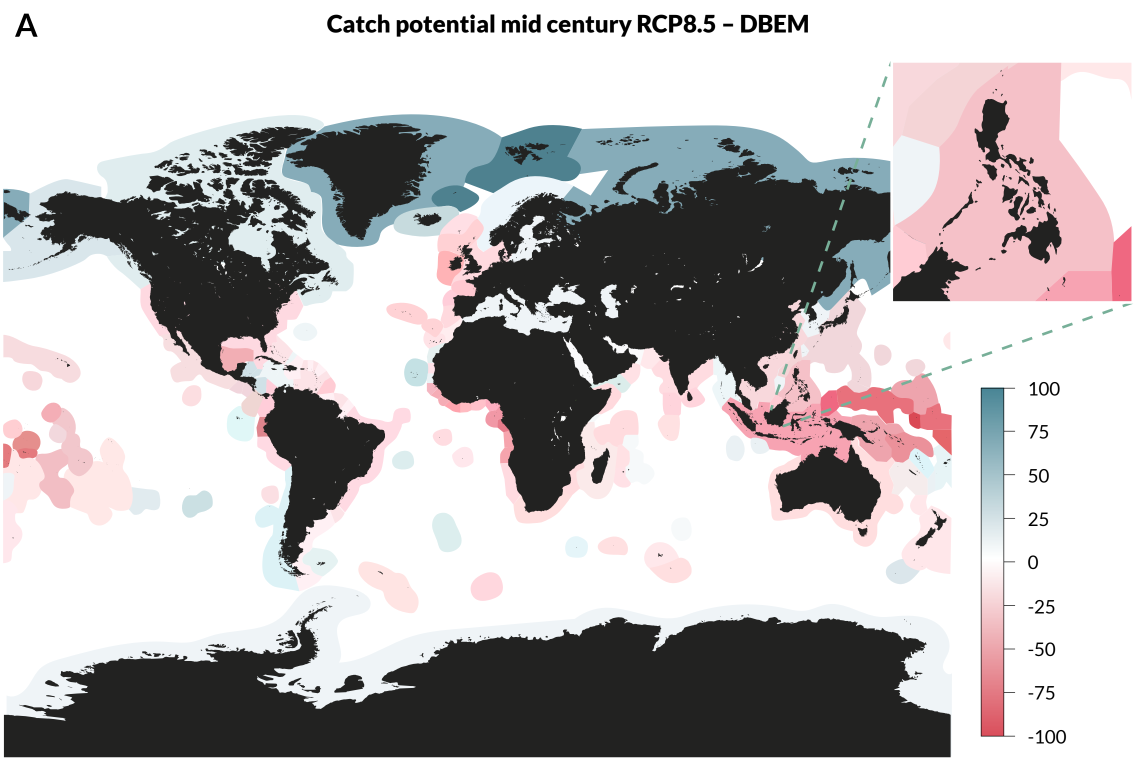


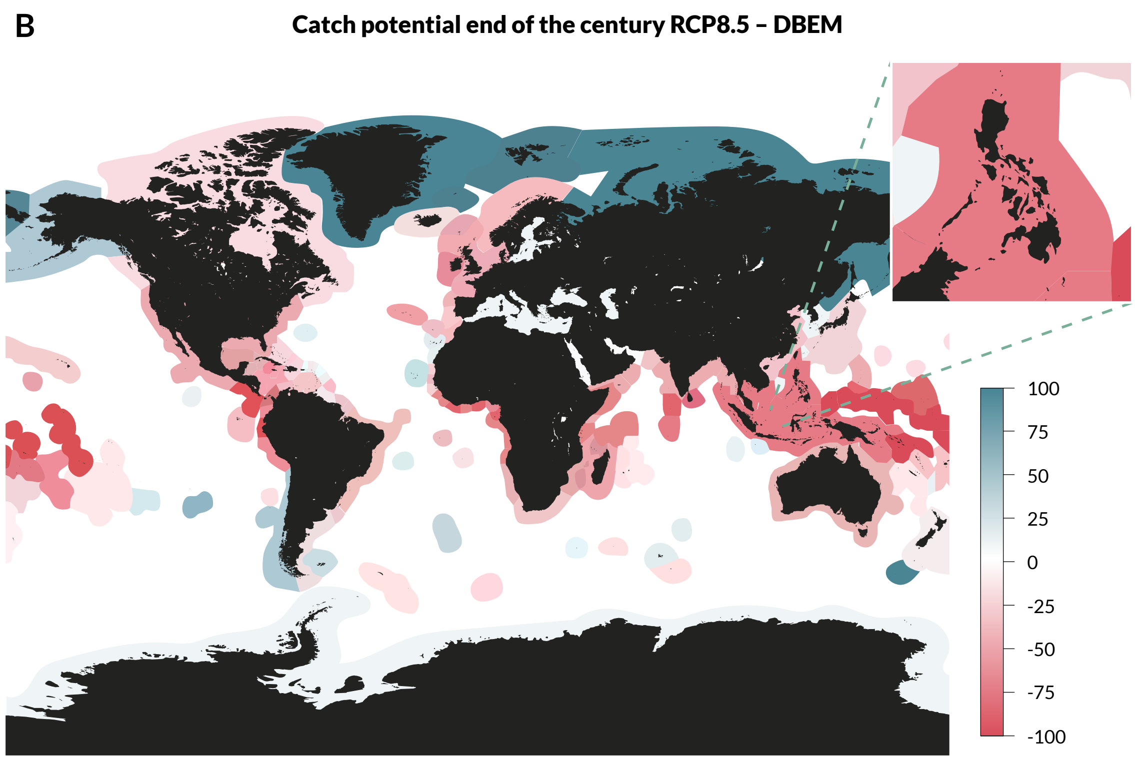


Source: modified from Cheung, Bruggeman and Butenschön, 2018.

FIGURE 4.6

DBEM projected changes in maximum catch potential (percent) under RCP8.5. A: by mid-century (2046 to 2055); and B: by the end of the century (2091 to 2100)





Source: modified from Cheung, Bruggeman and Butenschön, 2018.

4.3.3 DISCUSSION OF THE FINDINGS

The DBEM used in this report integrates the current understanding of the effects of climate change due to the increase of anthropogenic GHG concentration in the atmosphere under different emissions scenarios. It provides a quantitative assessment of the impacts on the ocean, marine ecosystems and fisheries through the changes of maximum potential catch for the overall fisheries and the specific fisheries of *Sardinella lemuru* in the Republic of the Philippines.

The results show that with a low emissions scenario (RCP2.6) no significant change in catch potential is expected for the fishery of *Sardinella lemuru* by mid-century, although it might present changes in size, growth and distribution due to the increase in temperature, increase in stratification and the decrease in primary production (Checkley *et al*., 2009; Cheung *et al*., 2009; Cheung, Bruggeman and Butenschön, 2018; Geronimo, 2018). Given the strong regional-based fishery of Sardinella species in the Republic of the Philippines, these possible distributional changes may be locally more important than any changes in production at the level of the Republic of the Philippines' EEZ. However, with a high GHG emissions scenario (RCP8.5) the catch potential of *Sardinella lemuru* might be significantly reduced by 2050. Accordingly, the maximum catch potential of all species combined in the Republic of the Philippines showed some decrease under RCP2.6 and a negative change under RCP8.5 by mid-century. The actual change in future catches will also depend on changes in fishing effort, which in turn depends on fisheries management and socio-economic factors (e.g. engagement/reliance on fishing, price of fish and cost of fishing) and fishers' behaviour (Colburn *et al*., 2016; Cheung, Reygondeau and Frölicher, 2016) but also on adaptation actions and the adaptive capacity of the sector (Poulain, Himes-Cornell and Shelton, 2018).

Consistent results of future potential changes in the species distribution in the Republic of the Philippines have also been shown in Geronimo (2018), where outputs from the Coral Triangle Regional Ocean Modelling System under scenario RCP8.5 and CMIP5 models under scenario RCP4.5 provide projections of habitat suitability for different commercial marine species. The results of projected climate change impacts on the Republic of the Philippine marine fish distribution showed the reduction of habitat suitability for all species with increasing carbon emissions, but the magnitude of change varied across species. In the case of *Sardinella lemuru*, there was some decrease of suitable habitat remaining under scenario RCP4.5, and a more significant decrease under the scenario RCP8.5 by mid-century.

The projected changes of maximum catch potential in *Sardinella lemuru* in the Republic of the Philippines by 2050 under RCP8.5 may be driven by the direct effect of the increase in temperature on growth, body size, mortality and fish distribution, but also by the decrease in phytoplankton/zooplankton availability and/or loss of habitat. Under optimistic climate change scenarios (RCP2.6), sardine may be able to adapt to milder projected changes. As the changes become larger in more pessimistic scenarios (RCP8.5), sardine production may experience a decrease because small pelagics tend to respond rapidly to changes in the environment and fishing efforts, and therefore may be rapidly affected by increasing impacts of climate change (Checkley *et al*., 2009). As mentioned above, even limited productivity changes at EEZ level (the assessment unit in this exercise) may have very significant impacts at local level, and along the entire value chain of Sardinella species, if resources shift distribution and/or seasonality.

A decrease in catch potential could have a significant impact on the livelihoods of coastal communities if management measures do not compensate for these changes. A decrease in the overall catch will cause a decrease in incomes, therefore limiting the possibility of subsistence from fisheries. Reduced catches would diminish the availability of fish protein, which can lead either to the need to increase imports or to a poorer diet, or ultimately to a reduction in food availability. As the protein consumption of the most vulnerable part of the population is based on small pelagics, and mainly sardines, the decrease of captures of this fishery could lead to additional sources of stress, malnutrition and loss of livelihoods.

The projected changes in maximum catch potential described in this report are indications of the risk of impacts and potential vulnerabilities of marine ecosystems to climate change, and the DBEM model used has provided results that are qualitatively comparable with projections from other models, and consistent with alternative species distribution models (Cheung *et al.*, 2016b). However, these models contain some uncertainties that need to be considered when interpreting these results (Cheung, Bruggeman and Butenschön, 2018; Cheung, Reygondeau and Frölicher, 2016; Cheung *et al.*, 2016a, b), including:

Changes in catch potential represent future changes of the productive capacity compared to the current capacity of the region under study. They are a proxy of the MSY and their equivalence with realized catches in the future will depend on current and future exploitation and management practices of the fishery (Barange, 2019).

The range of the projected climate changes and the related ecosystem responses between the outputs of the different Earth system models is considerable and often exceeds the average change itself (Bopp *et al.*, 2013). This model's uncertainty is due to differences in the parameters and structure of the Earth system models.

The relatively coarse spatial resolution (0.5 ° x 0.5 °) of the Earth system models used by the DBEM model might not represent well enough the Republic of the Philippines' internal seas and numerous islands. The Earth system models have substantial biases in coastal, estuarine and upwelling regions. Consequently, fisheries operating very close to shore and/or in upwelling or estuarine regions have low confidence. It is for this reason that the results in this report focus on EEZ-scale impacts.

Trophic interactions between exploited species are not represented in the DBEM model and may have impacts as sardines are a prey species in the marine environment.

The climate change projections are not designed to simulate a specific observed event (e.g. El Niño), or predict a future event, nor their temporal or spatial scales (Guilyardi *et al.*, 2009). In the Republic of the Philippines, municipal fishers operating in nearshore coastal waters had a lower CPUE during El Niño events. (Guerrero, 1999).

The model does not include mechanisms related to the capacity of fish species to adapt to climate change over time, or the possibility that some species not currently important for the fishing sector may be able to tolerate and increase their biomass under future environmental conditions.

The model does not include the occurrence of extreme weather events. Typhoons in the Republic of the Philippines are frequent and have serious consequences for the fishing sector. For example, impacts of Typhoon Haiyan severely disrupted the livelihood of fishers and resumption of fishing activities ranged from a week to more than a month (Monteclaro *et al.*, 2018).

4.3.4 POTENTIAL RESPONSES

Without a strong global response to the threat of climate change, current emission tendencies are heading to a scenario with high GHG concentrations in the atmosphere (IPCC, 2018). Under these circumstances, the maximum catch potential of *Sardinella lemuru* might decrease significantly by 2050. To address the challenges described in this document and guarantee the long-term sustainability of the fishery for *Sardinella lemuru*, an adaptation plan that foresees immediate actions addressing the current state of resources and in preparation for future changes (i.e. planning, monitoring, research), as well as medium- to long-term actions to adapt to future changes may be needed.

While fishers, fish farmers and fish-related workers may be used to coping with a certain level of variability in natural resources, they would require adequate adaptive capacity and should be ready to take measures to deal with potential impacts of climate change. Low-income population groups, in particular, often lack the financial and technological capacity to adapt effectively to sudden changes or long-term changes. Therefore, it is of critical importance to provide adequate responses to the threat of climate change, particularly in regions where climate change impact is expected to be high and the dependency on fisheries is also substantial (Barange *et al*., 2014), such as the case of the Republic of the Philippines.

A critical step towards facilitating fisheries and aquaculture adaptation to climate change is to provide tools and approaches that strengthen the adaptive capacity of the sector. This requires the allocation of dedicated funds and human resources, as urged by the Paris Agreement, and will benefit from the use of the FAO's Adaptation Toolbox. According to Poulain *et al*. 2018, there are three fundamental strategies to reduce impacts and take advantage of opportunities from climate change: institutional adaptation, livelihood adaptation, and risk reduction and management for resilience. All three are needed and they are not mutually exclusive. Adaptation is an iterative process that incorporates system feedbacks over time and includes:

- a cyclic vulnerability assessment of the sector, where the scope and the objectives are set;
- the development of a climate adaptation strategy based on the results of the vulnerability assessment; and
- the implementation, monitoring and evaluation of the climate adaptation strategy (Barange *et al*., 2018).

Specific potential responses and further guidance on the implementation of the Adaptation Toolbox for the specific case of the Republic of the Philippines are discussed in detail in a separate document prepared by FAO.

In what concerns the fishing sector, any adaptation plan should include the implementation of a fisheries management framework that allows for a rapid and efficient adaptation to changes. As a first step, the management framework should address existing challenges to be ready for future changes. Resources that are already under stress (e.g. with too high fishing pressure or already showing low biomasses) need to be recovered to improve their capacity to adapt to climate change. Adaptive management systems should be developed and implemented to accommodate future changes in the productivity of the ecosystem and the status of the different fish stocks. Different studies suggest that most marine capture fisheries in the Republic of the Philippines are overexploited and some fish stocks are depleted, even though the catch value has continued to increase over the years (Briones, 2007; Anticamara and Go, 2016).

Examples of measures leading to an improved management of fish resources are available in the literature, including:

the implementation of measures directed towards the regulation or reduction of fisheries exploitation and other human activities impacting the fisheries, to allow fisheries to rebuild or recover, including spatial management measures;

- the inclusion of fishers, consumers and other stakeholders in fisheries management;
- the improvement of fisheries science, monitoring and management capacities; and
- the identification of alternative livelihoods, through improved education and acquisition of new skills by fishers and their families (Anticamara and Go, 2016).

Adaptation should also address potential changes in the distribution of species that may facilitate the appearance of new species of potential interest for the fishery. In these cases, it is important that the sector adapts to the new opportunities, through the sustainable development of new fisheries, including the introduction of these species in the market.

In the case of the Republic of the Philippines, some studies already exist showing the vulnerability of fisheries to climate change and provide examples of positive effects of adequate fisheries management measures. A vulnerability assessment on sardine in Zamboanga city using FishVool (Jacinto *et al*., 2015) has provided information to assist local and national governments to identify areas and commodities that are vulnerable to climate change and need urgent adaptation measures. The assessment revealed an overall medium vulnerability (low exposure, medium sensitivity, and low adaptive capacity) for the sardine fishing sector (Jacinto *et al*., 2015), and called for actions to increase the resilience of this fishery.

A positive example of management of changes in abundance of sardine in the Republic of the Philippines is the implementation of the closed fishing season policy in Zamboanga Peninsula to allow for a more productive spawning season and address the declining fish catch. Other programmes have also been implemented to reduce sardine catch wastage during the glut season, such as the Regional Fisheries and Livelihoods Programme in Zamboanga del Norte province, which provided technology transfer and training to reduce sardine wastage (Sobreguel, 2013).

In addition to the above, a National Sardine Management Framework Plan 2020–2025 for sardines has been collectively developed by fisheries stakeholders (BFAR, 2020). This plan includes harvest control measures such as minimum size, proportion of juveniles, CPUE of indicator gear types and exploitation rates, and addresses some of the issues identified in this document.

To address the challenges of a possible reduction of potential maximum catch, flexible frameworks have to be developed and implemented, learning from positive experiences such as the ones described above.

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Chapter 5

Discussion on possible adaptation responses to climate change for the sardine fisheries of the Republic of the Philippines

Florence Poulain and Marcelo Vasconcellos

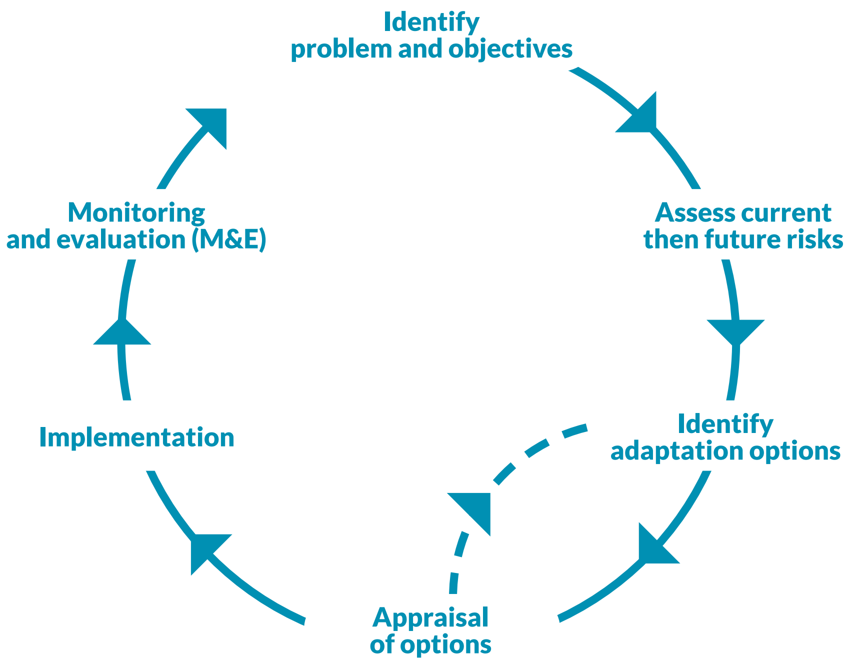
5.1 INTRODUCTION

In 2018, FAO produced a Technical Paper on the *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options* (Barange *et al*., 2018). The report examines the existing and projected impacts of climate change for marine and inland fisheries and aquaculture in the context of poverty alleviation and food security and provides insight into the main challenges and responses to climate change, including mitigation and adaptation options. In particular, it provides a portfolio of existing and recommended climate change adaptation strategies (FAO Adaptation Toolbox) organized in three categories: institutional adaptation, livelihoods adaptation, and risk reduction and management for resilience. These three categories are complementary and serve to guide the development of comprehensive adaptation plans and projects to reduce the vulnerability of the sector to climate change in developing and developed countries. This chapter builds on the FAO Adaptation Toolbox and discusses possible adaptation responses in the context of the sardine fisheries of the Republic of the Philippines.

5.2 THE ADAPTATION DECISION CYCLE

Adaptation is one of the central goals of the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement. Adaptation is defined as a process of adjustment in ecological, social, or economic systems to actual or expected climate change and its effects, which includes actions that moderate, avoid harm or exploit beneficial opportunities (Noble *et al*., 2014; UNFCCC, 2018). The adaptation decision cycle is generally represented as in Figure 5.1.

FIGURE 5.1
Adaptation planning cycle



Source: Adapted from Willows, et al., 2003; Bisaro and Hinkel, 2013.

The starting point in the adaptation planning cycle is to define the problem and the objectives the policy, programme or project are trying to address. The timeframe for the adaptation decision is important, both in terms of the climate risks it is trying to address (e.g. near term or long term), and in terms of adaptation decisions (e.g. whether it is an immediate project proposal or long-term adaptation policy). The second step is to undertake a vulnerability, impact or risk assessment of climate change on the sector to identify:

- current and future risks, including uncertainty and potential major threshold risks;
- target groups for which the adaptation tools and approaches will be used; and
- the risks of lock-in (e.g. irreversibility)[1].

There are a number of methods that have been used to assess impacts, vulnerability or risks (Brugère and De Young, 2015). This paper does not seek to reproduce these but to discuss in more detail adaptation options, in particular common issues in the management of small pelagic fisheries like the sardine fisheries in the Republic of the Philippines, the potential risks associated with climate change and broader possible adaptation options. The paper concludes by proposing next steps for appraising adaptation options in the context of the fisheries management plan for the sardine fishery.

5.3 MANAGING SMALL PELAGIC FISHERIES IN THE FACE OF CLIMATE CHANGE

Small pelagics (term used here to refer to species like herring, sardines, sardinellas and anchovies) are important fisheries resources worldwide, accounting for roughly 15 percent of global fisheries catches (FAO, 2020). Small pelagics are characteristically fast growing, have a short life cycle and are forage species in different marine ecosystems. These characteristics make their stocks highly susceptible to environmental changes which may affect productivity and recruitment success. Not surprisingly, some of the most extreme fluctuations in stock abundance and fisheries catches were observed in small pelagic fisheries (e.g. Peruvian anchoveta, California sardine, etc.). It has been shown for different stocks that these oscillations correspond closely to long-term climatic–oceanographic regimes of the oceans (Bakun, 1996). The dynamic behaviour of small pelagic stocks makes their management particularly challenging, requiring the explicit consideration of environmental changes in fisheries management decision-making.

There are at least four main reasons why we should engage in managing fisheries for small pelagics, in spite of their complex dynamics:

1. These renewable resources are finite, and their uncontrolled harvesting can lead to an undesirable situation of overfishing and yield loss.
2. They are common-pool resources and norms to control access need to be put in place to avoid a situation where the uncontrolled competition between users causes the overexploitation of the resources.
3. There is often a wide range of societal objectives and interests with the use of fisheries resources (e.g. subsistence, food security, fish meal production, etc.) and because of this, fisheries are prone to conflicts between the social actors involved in the activity. If

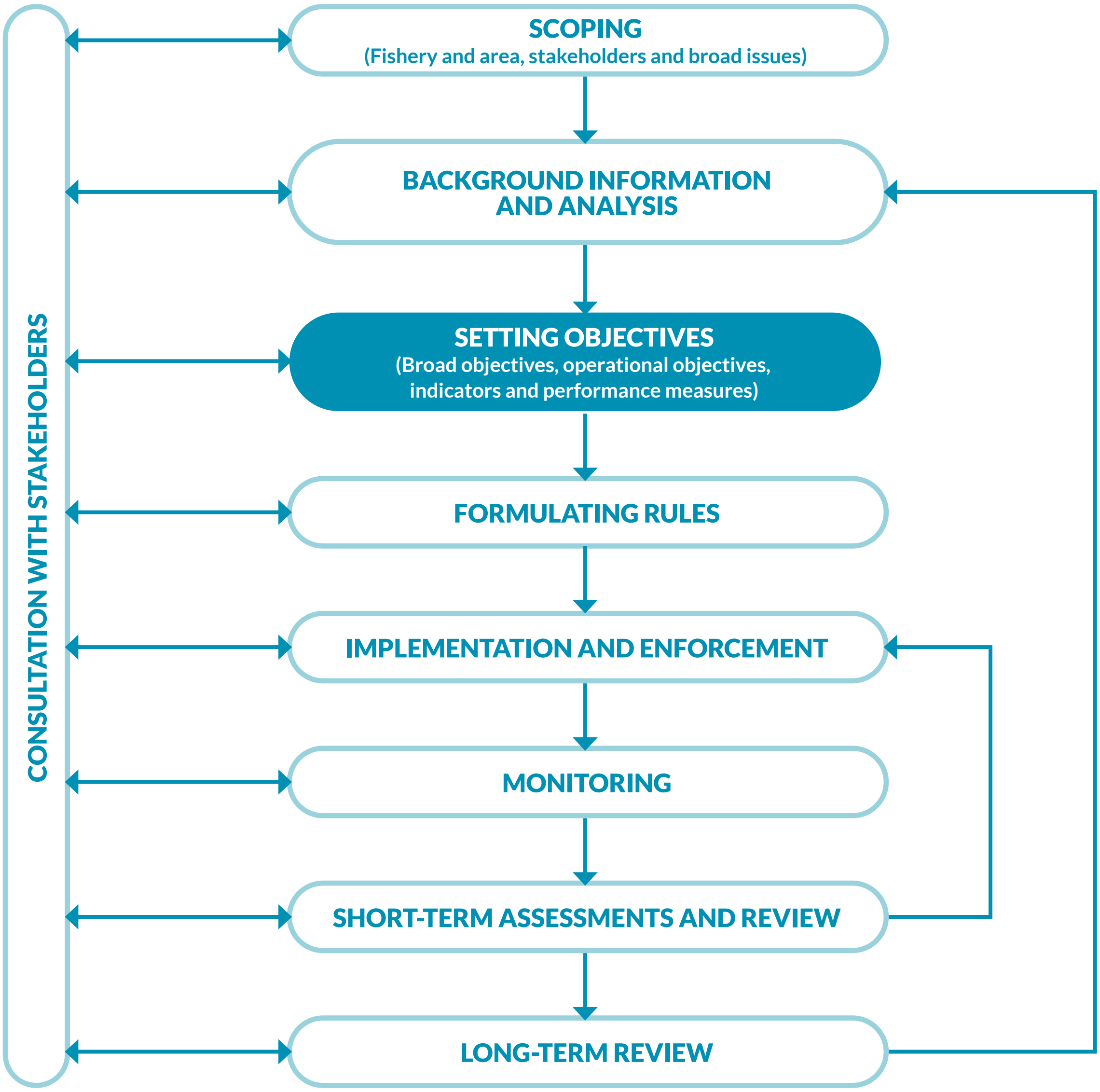
[1] Some decisions are extremely difficult or expensive to change later. They involve a degree of irreversibility and therefore there is a risk of locking-in future climate risks.

norms regulating access and uses are not well defined and enforced, social relationships can degenerate to a point of confrontation and tension.

4. There is a need to control unsustainable resource use practices, i.e. fishing techniques and harvesting patterns that cause undesirable effects on stocks and ecosystems (FAO, 2016).

Fisheries management involves a complex and wide-ranging set of tasks that collectively aim to address the above issues and achieve sustained optimal benefits from the resources. The management tasks are illustrated in Figure 5.2.

FIGURE 5.2
Generic steps in fisheries management

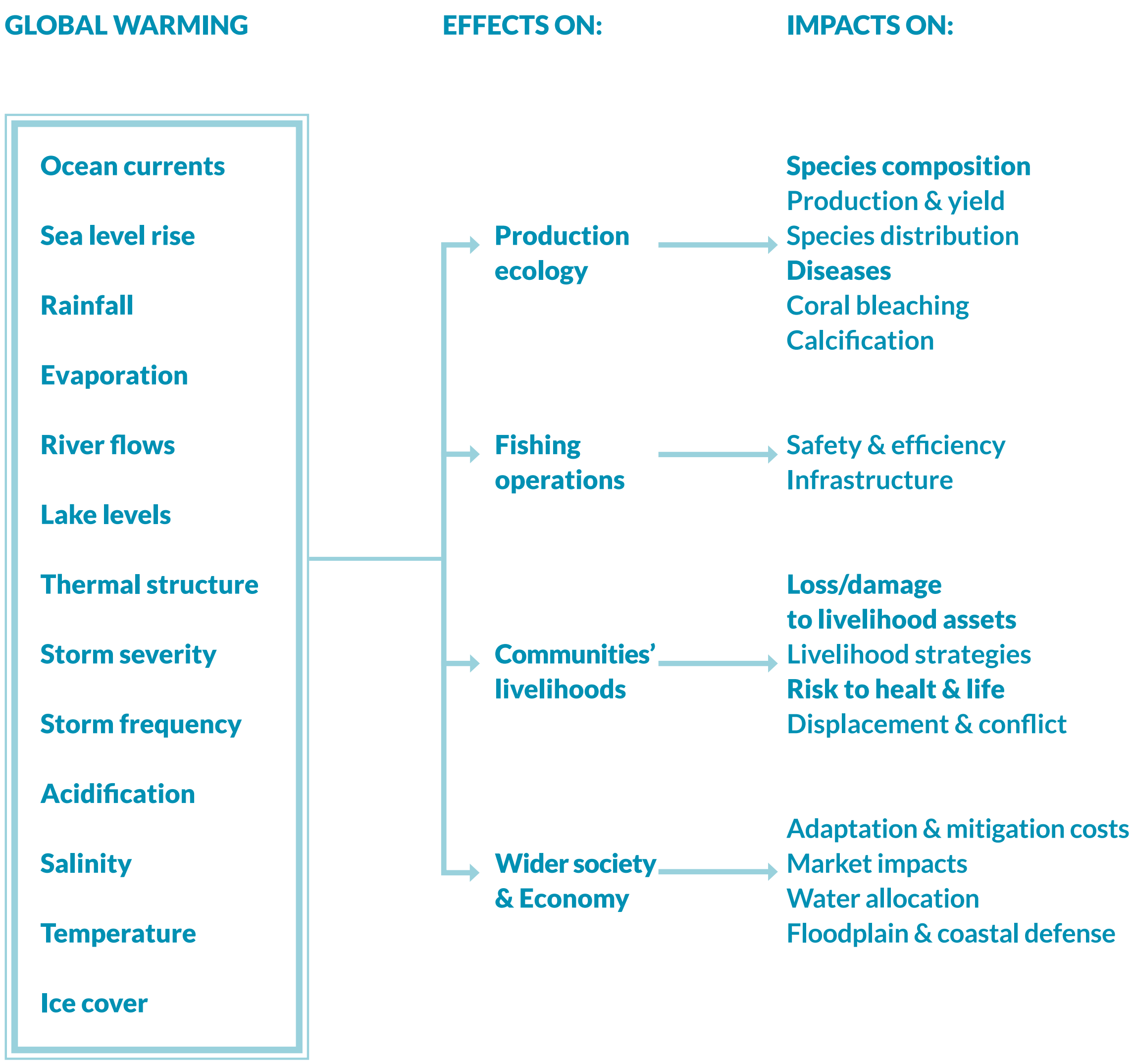


Source: Cochrane, 2002.

Climate change can have different implications for fisheries (Figure 5.3) and fisheries management needs to be prepared to cope with these impacts. Climate change drivers can cause changes in productivity, species composition, stock distribution and abundance, and also affect the conditions for fishing operations. Climate change can also impact the livelihood of fishers and the economic performance of fleets, and have consequences for the community and wider society in terms of food security, health and conflicts.

Some of these impacts can be addressed by adaptive fisheries management responses. Others will require complementary institutional, livelihood and risk management measures (described in other sections of this report). Most often fisheries are concomitantly affected by other non-climate related stressors and drivers (e.g. governance, markets, overfishing, habitat degradation, etc.) and climate change presents an additional concern to be addressed by managers.

FIGURE 5.3
Generic examples of pathways of the impact of climate change on fisheries



Source: Badjeck *et al.*, 2010.

Basic principles

Despite improvements in the understanding of climate change and its implications for fisheries, our capacity to forecast the impacts of future climate change scenarios presents high levels of uncertainty. Managing fisheries in the face of climate change is a special case of decision-making under uncertainties and risks (Walters, 1986). In these situations, management should follow a precautionary approach to avoid undesirable outcomes (FAO, 1996). Caution should be practiced in the different stages of management, from planning through implementation, enforcement and monitoring to re-evaluation (Table 5.1).

Table 5.1
Examples of precautionary actions to take in the different phases of fisheries management

Management planning	Explicit consideration of precautionary actions that will be taken to avoid specific undesirable outcomes. Consider a range of alternative actions to be evaluated against objectives, targets and constraints. Ensure broad acceptance of precautionary actions through appropriate consultations with stakeholders. Define objectives, targets, constraints, management measures and procedures to apply and adjust management measures. Set precautionary targets commensurate with the level of uncertainty, i.e., the higher the uncertainty the more conservative the targets should be (e.g. $F<F_{MSY}$). Give priority to the restoration of already overfished stocks, to avoidance of overfishing, and to avoidance of excessive harvesting capacity.
Implementation, monitoring, and enforcement	Collect all information relevant to ensuring that the plan is being executed and that it is achieving the desired results, including environmental and socio-economic data. Use best available information to monitor the fishery, including scientific and local/traditional knowledge. Set up procedures for stock assessments, rule setting, economic assessments, and communication of decisions and rationale to the public and fishing industry. Implement contingency rules to ensure compliance with targets in the face of major adverse events. Ensure appropriate systems of enforcement and penalties for non-compliance. Re-evaluate and adapt the level of precaution in the management system periodically, and as soon as it becomes apparent that the fishery inadvertently violates the targets and constraints established in the plan.

Source: FAO, 1996; Cochrane, 2002.

There are several precautionary measures that could be taken to avoid undesirable or unacceptable outcomes. Specifically, for overfished resources FAO recommends (FAO, 1996):

- Immediately limit access to the fishery and put a cap on a further increase in fishing capacity and fishing mortality rate.
- Establish a recovery plan that will rebuild the stock over a specific period with reasonable certainty. This will include several of the components below.
- Reduce fishing mortality rates long enough to allow rebuilding of the spawning stock. If possible, take immediate short-term action, even on the basis of circumstantial evidence, about the effectiveness of a particular measure. In some cases this can be accomplished by entirely closing some areas to fishing.
- When there is a good year class, give priority to using the recruits to rebuild the stock rather than increasing the allowable harvest.
- Reduce fishing capacity to avoid recurrence of overutilization. Remove excessive fishing capacity from the fishery; do not provide subsidies or tax incentives to maintain fishing capacity. If necessary, develop mechanisms to eliminate some fishing effort.
- Alternatively, allow vessels to move from an overutilized fishery into another fishery, as long as the pressure from this redeployment does not jeopardize the fishery that the vessels are moving into.
- Do not use artificial propagation as a substitute for the precautionary measures listed above.
- In the management plan, establish biological reference points to define recovery, using measures of stock status such as spawning stock biomass, spatial distribution, age structure, or recruitment.
- For species where it is possible, closely monitor the productivity and total area of required habitat to provide another indicator of when management action is needed.

In addition (and of relevance to the sardine fishery in the Republic of the Philippines), FAO recommends the following measures for artisanal and traditional fisheries (FAO, 1996):

- Keep some areas closed to fishing to limit risks to the resource and the environment. Also ensure that excessive fishing effort does not develop in the open areas.
- Delegate some of the decision-making, especially area closures and entry limitations, to local communities or cooperatives.
- Ensure that fishing pressure from other segments (e.g. industrial) of the fishery does not deplete the resources to the point where severe corrective action is needed.
- Investigate the factors that influence the behaviour of harvesters to develop approaches that can control fishing intensity. For example, improving incomes of individual harvesters may reduce pressure on resources.

As noted above, the precautionary approach is acknowledged as a key underlying basis for incorporating uncertainty into decision-making, so as to “err on the side of caution”. However, while accepting that uncertainty will continue to be a significant part of reality, experience should allow for improving the ability to make decisions. In this regard, adaptive management is an approach that takes the view that resource management policies can be treated as “experiments”, whether actively or passively, from which managers can learn and then adapt or change (Walters, 1996; Hilborn and Walters, 1992; FAO, 2009).

Adaptive management is a structured and iterative process which aims at optimizing decision-making and decreasing uncertainty over time. It can be described as “learning by doing" and is – alongside the precautionary approach – valuable for addressing uncertainty when managing fisheries. It allows for the incorporation of feedback from the fishery system to revise policy and management systems. Revisions are then followed by further implementation and experimentation, shaping subsequent policy and management actions.

To make the process effective, it is essential that the "experiments" and their results are appropriately documented, i.e. there is a need for a robust monitoring system providing information on the performance of the various components of the management system through the use of indicators and reference points (also discussed under the precautionary approach).

Another aspect of adaptive management is "robust management" implying that the choice should fall on management measures that are relatively insensitive to uncertainty so that use of these management measures has a high likelihood of producing outcomes that are reasonably acceptable, even with limited knowledge of the fishery and ecosystem. This aspect is particularly relevant when dealing with the different plausible scenarios about future climate changes.

Regarding the choice of management measures, several authors emphasized the importance of "redundancy" in management measures and tactics for successful fisheries management outcomes, especially when uncertainties are high (Gutierrez, Hilborn and Defeo, 2011; Stefansson and Rosenberg, 2005). Stefansson and Rosenberg (2005) for instance, showed that combining more than one type of primary direct control on fishing provides a greater buffer to uncertainty than any single form of fishery control alone. The authors showed, for example, that combining closed areas with input (effort limits) and/or output (catch quota) controls, performs better in reducing the risk of stock collapse and maintaining both short- and long-term economic performance than single measures alone.

Potential fisheries management responses to the effects of climate change

Regarding the effects of climate change on fisheries resources in general, there are two main issues that are of concern to fisheries management: how to deal with the trends and variability in abundance and productivity; and with the changes in stock distribution. These issues can have direct consequences on the income of fishers, livelihoods and food security.

There are two different approaches regarding how to adapt harvest rates (or fishing intensity) to trends and variability in stock productivity. One approach, based on the premise of an enhanced understanding of the factors controlling recruitment, relies on the use of understanding to forecast stock productivity and adjust harvest rates accordingly. Using this approach, higher fishing mortalities would be allowed under an improving environment, while under unfavourable conditions, lower fishing mortalities would apply (Barange *et al.*, 2009; Checkley *et al.*, 2009; Hill, Crone and Zwolinski, 2018).

Where there is stock overfishing, one could also argue for decreasing fishing pressure during a favourable period to allow stock recovery (see precautionary approach). To implement such systems Fréon *et al.* (2005) proposed, for instance, a two-level (short- and long-term) management strategy to cope with interannual and interdecadal variations in productivity. The strategy would involve adjusting the effective fishing effort (days at sea) of the fleet at the interannual scale and adjusting the nominal effort (number of boats) at the interdecadal scale. Harvest control rules adaptable to the productivity of the stock have been implemented in the management of the California sardine (see box 5.1).

Box 5.1
Adaptable harvest control rule for the California sardine

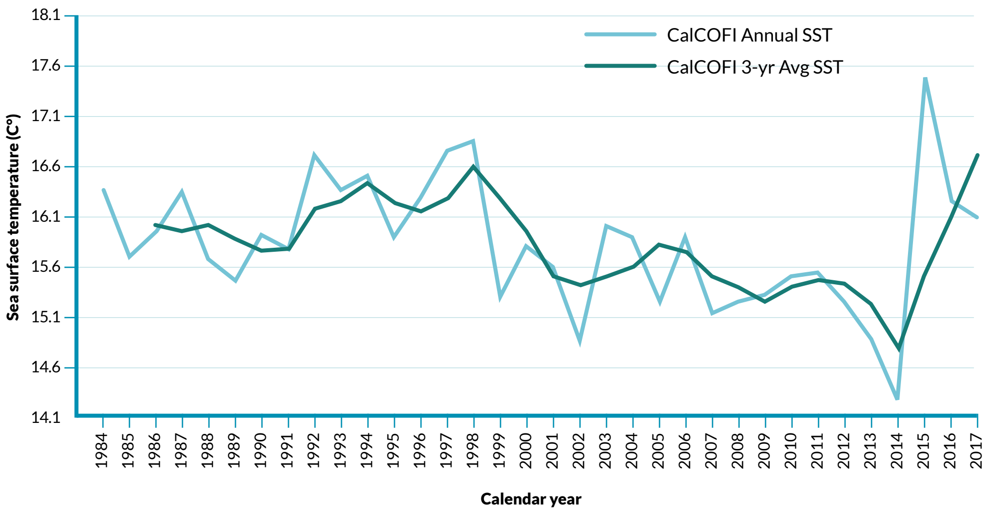
Periods of warm sea surface temperature (SST) in the California Current ecosystem are associated with good recruitment and higher productivity for California sardine. It has been shown that SST is a good proxy for environmental conditions influencing positive or negative surplus production of the species. The management of the California sardine fishery takes into account this effect by applying a harvest control rule that depends on a three-year running average of SST. The harvest control rule for the 2018 to 2019 management cycle was:

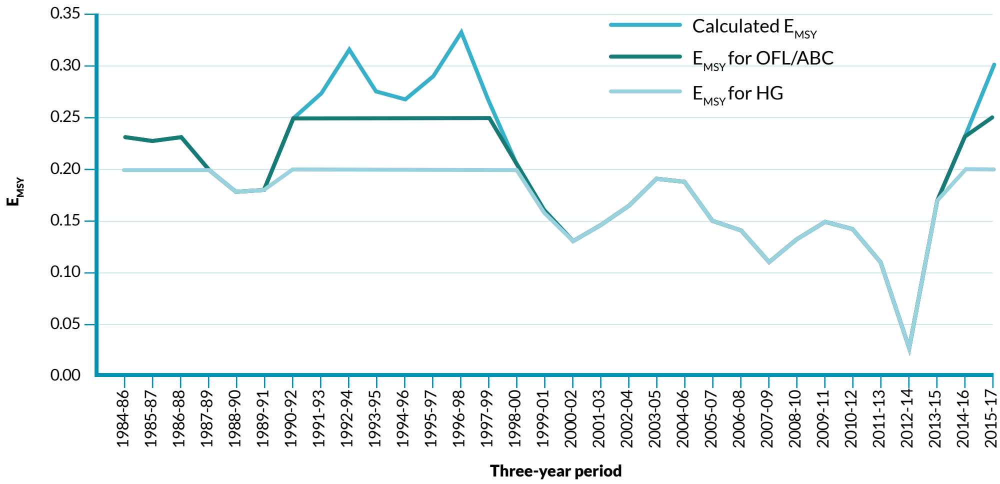
HG = (Biomass – cut-off) • Fraction • Distribution

- HG is the total the United States of America directed harvest (catches) from July 2018 to June 2019;
- Biomass is the assessed sardine stock biomass in July 2018;
- Cut-off (150 000 metric tonnes) is the lowest level of biomass for which directed harvest is allowed;
- Fraction (exploitation rate (E_{MSY}) bounded 0.05–0.20) is the percentage of biomass above the cut-off that can be harvested; and
- Distribution is the average portion of biomass assumed in the United States of America waters (87 percent in this particular management cycle).

In an attempt to make the control rule responsive to environmental forcing, control rules were constructed with Fraction (E_t) for each year based on a regression function relating E_{MSY} to a range of average SST values:

E_{MSY}= –18.46452+3.25209(T)–0.19723(T^2)+0.0041863(T^3), where T is the three-year running average SST.





SST, °C (upper panel) and calculated EMSY values (lower panel) for the California sardine
Source: Hill, Crone and Zwolinski, 2018.

The challenge with this approach is that, in most situations, uncertainties about the relationship between environmental conditions and stock productivity are simply too high to enable the use of this type of information for decision-making. In the case of the anchovy fishery in the Benguela system, for instance, De Oliveira and Butterworth (2005) show that an environmental index needs to explain roughly 50 percent or more of the total variation in recruitment before a management system that takes account of such information to define harvest rates starts to show benefits in terms of risk and average catch. This level of predictive capacity is likely to be unattainable in many fisheries, especially in data-limited areas.

The second recommended approach to cope with variability in productivity assumes that there is little prospect that fisheries research will significantly reduce the uncertainties in the factors affecting stock productivity, and therefore that the focus should be in developing management strategies that are robust to the environmental changes affecting stock productivity (Walters and Collie, 1988).

The constant or fixed harvest rate strategy, where management aims to harvest the same proportion of the stock each year, is one example of such a strategy. Walters and Parma (1996) show that constant harvest rate strategies produce very close to optimum return compared to perfect information about long-term changes. Only in cases of abrupt and uncorrelated changes, knowing and timely adaptation to the changes would perform better. The authors conclude that it may be more cost effective to invest in research on how to implement fixed harvest rate strategies (which will require a combination of improved stock size assessments and stringent regulatory measures) than to invest in research on explaining and predicting climatic effects on stocks.

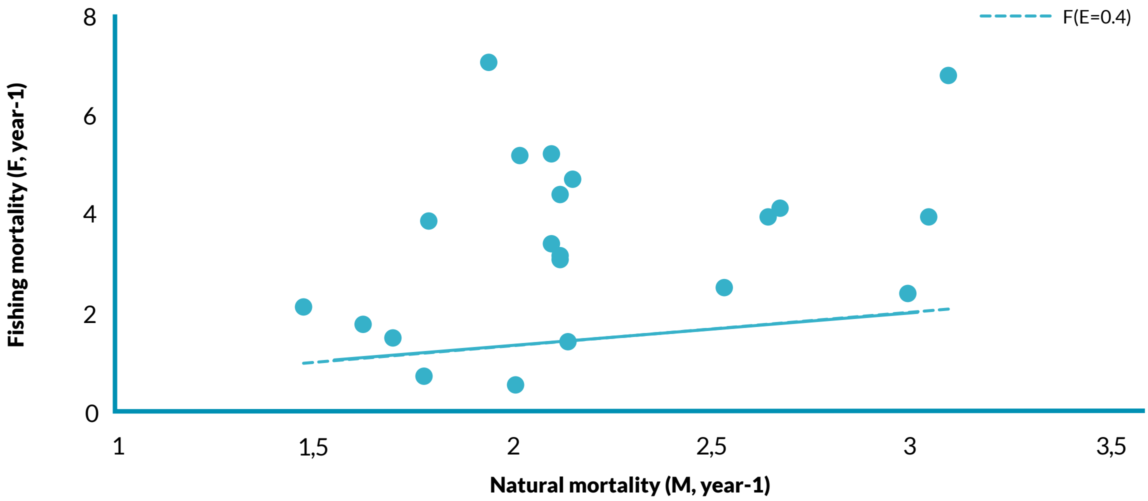
The definition of the optimum harvest rate will depend on the life history characteristics of the species. For small pelagic stocks, a meta-analysis conducted by Patterson (1992) showed that most cases of stock collapse occurred when F (fishing morality) was higher than 0.6 M (natural mortality). Patterson's analysis thus indicates that the implementation of exploitation rates (E=F/Z) at or below 0.4 can be a robust strategy to cope with the risk of small pelagic stock collapse in view of variable environmental conditions. This exploitation rate has been used, for example, in the Mediterranean Sea as a biological reference point for small pelagic stocks (General Fisheries Commission for the Mediterranean and the European Union's Scientific, Technical and Economic Committee for Fisheries).

Available stock assessment for sardines in the Republic of the Philippines indicates that stocks have been under high fishing pressure since the 1950s, when the first stock assessments were conducted, with exploitation rates generally above 0.4 (Figure 5.4). Target exploitation rates between 0.3 and 0.5 are being proposed in the draft National Sardine Management Framework Plan (NSMFP) (Campos and Bagarinao-Regalado, Chapter 2, this volume). In view of the possible long-term decrease in productivity (Fernandez-Reguera, Chapter 4, this volume), the adoption of target exploitation rates towards the lower end of this range would be advisable as a precautionary measure.

Developing a sardine fishery management system resilient to the effects of climate change in the Republic of the Philippines would require a substantial decrease in fishing mortality and a strategy to keep exploitation rates relatively constant and within sustainable precautionary levels. The question then becomes how to implement such a system adapted to the local context?

FIGURE 5.4

Estimated fishing (F) and natural (M) mortality rates for *Sardinella lemuru*, *Sardinella fimbriata*, *Sardinella gibbosa* and *Amblygaster sirm* in the Republic of the Philippines. The straight line represents the expected F values at an exploitation rate of 0.4



Source: F and M estimates from the review by Campos and Bagarinao (Chapter 2, this volume).

The most successfully managed stocks of small pelagics rely on a scientific programme of advice based on annual, or within season scientific assessments of the stock and harvest rules defining the allowed catch levels (Barange *et al*., 2009). In these systems the assessment of the stocks is based on data obtained from fishery-independent surveys (e.g. hydroacoustic surveys). The use of fishery-independent data is preferable given that the behavioural characteristics of the species (e.g. shoaling, range contraction, etc.) and the dynamics of the main commercial purse seine fisheries make catch per unit effort data an unreliable indicator of changes in stock abundance. The success of these systems hinges on accurate and regular assessments of the stock and on effective monitoring and control of the catches.

When the implementation of such catch control systems is not feasible (due to costs, logistics, capacities, etc.), the alternative is to rely on a combination of technical regulatory measures (see Table 5.2 for examples) and adopt an adaptive management system where measures are adjusted regularly, based on the results of stock assessment, to ensure that fishing mortality is kept within the target.

Taking into account the results of the last available stock assessment of *Sardinella lemuru* (based on 2014 data from Zamboanga Peninsula) (Chapter 2, this volume), the current fishing mortality (F_{curr}=2.13 year^{-1}) is about two times higher than the fishing mortality at the precautionary target E=0.4 (F_{target}=0.98 year^{-1}). Reaching this target will require substantial decreases in fishing effort and improvements in the exploitation pattern of the species. Different combinations of measures could be applied (see Table 5.2 for examples) in different management strategies over time (e.g. decreasing fishing effort and capacity with time to reach target exploitation rates). The trade-offs of these different management measures and strategies should be properly evaluated in consultation with fisheries stakeholders, considering their effects on stocks, livelihoods and other socioeconomic indicators.

Table 5.2

Examples of technical management measures and their advantages and disadvantages in the context of small pelagic fisheries. Comments also provided on the application of the measures in the sardine fisheries in the Republic of the Philippines

Management measure	Advantages	Disadvantages	Comments in relation to the Philippines
Fish size control	• Allows protection of key stages, including juveniles and first spawners. • Protecting first spawners' resilience to overfishing under unfavourable environmental regimes.	• Not always easy to implement without avoiding fish discarding due to poor gear selectivity.	• Minimum sizes (first maturity) are recommended in the draft NSMFP.
Gear control	• Might help protection of key stages if gear selectivity can be controlled through mesh size or gear regulation. • Avoid unwanted impacts on ecosystem caused by destructive fishing gears.	• Costs of modifying and substituting gears could hamper implementation. • Less effective in multi-specific fisheries.	• Small mesh size regulations excludes the main gears used for sardines and for Dulong (fries) – which are mainly composed of juvenile sardines. • Local Government Units (LGUs) are responsible for enforcement but have limited capacity. • Distinctions also create confusion for regulatory bodies.
Control of fleet capacity	• Easy to enforce. • Limit risk of overfishing. • Mitigate dissipation of economic gains caused by open access regime.	• Not species-specific. • Risk of overexploitation if increase in catchability and efficiency (technology).	• Draft NSMFP recommends temporary (three years) freeze in fishing capacity by means of moratorium on fishing licenses.
Control of effort	• Specially applicable for species-specific fisheries. • Limits fish discarding.	• Difficult to calibrate effort of several fleets. • Uncontrolled changes in F if changes to catchability. • Difficult to implement and enforce. • No reductions of overhead costs. • Might create socio-economic difficulties.	• Probably more appropriate for the large commercial vessels than the municipal small-scale fisheries.

Management measure	Advantages	Disadvantages	Comments in relation to the Philippines
Time closures	• Allows protection of some developmental stages (when recruitment and spawning periods are well defined). • Easier to enforce and normally easily understood by actors (low resistance). • Limits fish discarding.	• Difficult to decide on the optimal season in view of different socio-economic objectives and consequences. • Tendency to excessively increase catch in the open seasons may reduce effectiveness of the closures. • No reduction of overhead costs.	• Temporary closures applicable to some of the main fishing grounds (Viasaya and Zamboanga). • Temporary closure hard to implement by LGUs – multi species fisheries. • Low compliance due to lack of alternative livelihoods. Spawning season varies interannually due to environmental conditions (need for a flexible season). • Need for harmonized season among LGUs - good example of coordinated ordinances by 11 municipalities for 22 day closure (Visayan Sea). • Support of canning industry key for success in Zamboagan closure. • Use of cold storage and other strategic actions by sardine canning industry reduced negative effects of time closure on industry. • Important role of assistance programmes to reduce negative impacts on fishers. • Oversupply during glut season (after re-opening) creates fish wastage.
Area closures (including marine protected areas, MPAs)	• Allows protection of some developmental stages (when nursery and spawning areas are distinct). • Protection of ecosystems.	• Not protective enough for pelagic species due to their migratory behaviour. • Difficult enforcement without means of monitoring of vessels.	• Large commercial vessels not allowed to operate in municipal waters (< 15 km from coast). • Encroachment is common due to poor enforcement. • Over 1 300 MPAs had been established nationwide, over 50 percent of these have areas less than 10 ha, focusing primarily on coral reefs. • Only 10 percent to 15 percent with some level of implementation. • In general, MPAs do not include substantial portions of sardine fishing grounds.

Source: Vasconcellos and Pitcher, 1998; Freon *et al*., 2005; Brillo *et al*., 2016; Sobreguel, 2013; Campos and Bagarinao-Regalado, Chapter 2, this volume.

Addressing climate-driven changes in distribution

The changes in environmental conditions associated with the different drivers of climate change can affect the habitat suitability for marine species and consequently influence their distribution and spatial dynamics. Various studies have documented persistent changes in the spatial distribution of marine species related to changes in oceanographic processes associated with climate change (Brander *et al*., 2003; Poloczanska *et al*., 2013). These changes are expected to continue or accelerate in the next decades under different climate change scenarios (Pinsky *et al*., 2018).

The distribution shifts can affect fisheries management in different ways (Pinsky *et al*., 2018). First are the effects on the defined geographic boundaries of the stock being managed, facilitating access to new fisheries/users and potentially eroding any previously established management system. Resource overfishing can also be exacerbated when new users have not agreed on responsibilities for resource conservation, and when the change creates disincentives for those previously committed to conservation if they do not have control outside of their management boundaries. Stocks can straddle political boundaries internal to a state, between states and between states and the high seas, requiring different levels of cooperation among jurisdictions for their effective management.

The shifts in stock boundaries will also have implications for the assessment of stocks and the management advice resulting from these assessments (Link, Nye and Hare, 2011). Stocks can move, expand, contract, split and merge with stocks in other jurisdictions and if these changes are not captured in the assessment, they will lead to incorrect impressions regarding stock status. Assessments based on static stock boundaries will lead to different management measures and potential negative consequences, either in terms of risk of overfishing or underfishing. If an area of a stock is shifting and its stock area is incorrectly specified, then reference points and management measures will tend to be at levels that are not feasibly obtainable given such shifts. Recognizing and properly monitoring the shifts in distribution will enable managers to better evaluate the option of engaging in transboundary management.

In the case of the Republic of the Philippines, there are two potential effects of the shifts in distribution, which will require different types of governance change and adaptation. The first involves shifts crossing national boundaries and seems to be likely only in the fishing grounds of the Sulu Archipelago, which borders Malaysia. All other main fishing grounds/stocks seem to be restricted to archipelagic waters and are relatively isolated from other national jurisdictions by open waters not suitable for sardines. The second effect, expected to occur with high frequency, is the shift between the jurisdiction of local LGUs and between LGUs and national waters (beyond 15 km from shore).

In relation to the latter, the Republic of the Philippines has a mix of national and municipal regulatory frameworks for fisheries management (Campos and Bagarinao-Regalado, Chapter 2, this volume). Areas within 15 km from shore are under municipal jurisdiction and managed by LGUs. The national legislation forbids the operation of commercial vessels in these areas, although some LGUs may issue licenses for small commercial vessels (3 gross tonnage [GT] to 20 GT) to operate in the municipal waters.

Boundaries of the LGUs are not well defined and the LGUs have, in general, limited enforcement capacity, resulting in frequent encroachment by large commercial vessels into municipal waters. It is not clear what the level of harmonization of management measures is across LGUs, but it would be an important issue to address if stocks are shared across jurisdictions, and fleets (especially the commercial vessels) are allowed to operate in different jurisdictions.

It is worth noting that the draft NSMFP foresees the establishment of fisheries management areas (FMAs), apparently encompassing different LGUs and with inclusive fishery scientific advisory committees. The establishment of such FMAs would mitigate some of the regulatory issues raised above and could also be a proper strategy to adapt to the potential changes in stock distribution resulting from climate change.

Adapting to the straddling of stocks across national boundaries will require regional assessments and management. If such a distribution shift is considered likely to occur, then the first step is to engage in scientific cooperation and sharing information between countries to monitor changes in stock distribution and the collection of standardized data for a joint assessment of stock status. The scientific cooperation would result in improved information about the stock and a better understanding of the risks and required management measures to be adopted by individual countries.

With improved knowledge, countries will be in a better position to evaluate the merits of moving towards joint management of shared resources, either through the harmonization of management measures, or the introduction of agreed rules for harvesting the resource sustainably.

5.4 BROADER ADAPTATION RESPONSES TO CLIMATE CHANGE

5.4.1 SOCIO-ECONOMIC AND INSTITUTIONAL BACKGROUND

Adaptation does not take place in a vacuum. It is part of an existing socio-economic and institutional context that needs to be examined to identify the best available and viable adaptation options, including potential (economic, governance, information, etc.) barriers that will need to be addressed.

In the Republic of the Philippines, sardine fisheries constitute a dynamic contributor to the country's economy as well as a provider of employment and nutritious food to many coastal communities. However, paradoxically, fishing communities remain among the poorest of the rural poor. There are several reasons for this, including climate change and non-climate related processes.

Among the climate related risks, the Republic of the Philippines is third among the 171 countries that are the most exposed (52.46 percent) to natural disasters. Climate hazards that have a direct impact on sardine fishing communities and the related fishing industry are sea level rise and typhoons (Baticados, Chapter 3, this volume).

In addition, the climate change risks identified above (e.g. changes in fish productivity, species composition, stock distribution and abundance) will affect or are already affecting the livelihood of fishers, the economic performance of fleets, food security, and health and conflict.

To guarantee the sustainability and safety of the livelihoods that are dependent on fisheries, a number of measures are available to complement the management options discussed above. These are presented in the following sections.

5.4.2 THE FAO ADAPTATION TOOLBOX

To advance the analysis of adaptation, Poulain, Himes-Cornell and Shelton (2018) have grouped recommended adaptations in the fisheries and aquaculture sector into three main non-mutually exclusive categories:

1. Institutional adaptation, i.e. interventions, mainly on the part of public bodies, that address legal, policy, management and institutional issues, including public investments and incentives.
2. Livelihood adaptation, i.e. interventions, mostly in the private sector, that include a mix of public and private activities, within or among sectors, most commonly through diversification strategies within or outside the sector to reduce vulnerability.
3. Risk reduction and management for resilience, i.e. interventions that include a mix of public and private activities to promote early warning and information systems, improve risk reduction (prevention and preparedness) strategies and enhance response to shocks.

Selected examples of adaptation tools and approaches in capture fisheries are shown in Table 5.3 and are summarized in the subsequent sections.

Table 5.3
Types and selected examples of adaptation tools and approaches in capture fisheries

INSTITUTIONS
Public policies
Public investments (e.g. research, capacity building, sharing best practices and trials, communication)
Climate change adaptation policies and plans address fisheries
Provide incentives for fish product enhancement and market development
Remove harmful incentives (e.g. for the expansion of fishing capacity)
Address poverty and food insecurity, which systemically limit adaptation effectiveness
Laws and regulations
Flexible access rights to fisheries resources in a changing climate
Dispute settlement
Adaptive legal rules
Regulatory tools (e.g. move away from time-dependent effort control)
Institutional frameworks
Effective arrangements for stakeholder engagement
Awareness raising and capacity building to integrate climate change into research/management/policy/rules
Enhanced cooperation mechanisms, including between countries to enhance the capacity of fleets to move between and across national boundaries in response to change in species distribution
Management and planning
Inclusion of climate change in management practices, e.g. ecosystem approach to fisheries, adaptive fisheries management, co-management
Inclusion of climate change in integrated coastal zone management
Improved water management to sustain fishery services (particularly inland)
"Adjustable" territorial use rights
Flexible seasonal rights
Temporal and spatial planning to permit stock recovery during periods when climate is favourable
Transboundary stock management to take into account changes in distribution
Enhanced resilience by reducing other non-climate stressors (e.g. habitat destruction, pollution)
Incorporate traditional knowledge in management planning and advice for decision-making
Management/protection of critical habitats for biodiversity and recruitment
LIVELIHOODS
Within sector
Diversification of markets/fish products, access high value markets, support diversification of citizens' demands and preferences
Improvement or change of post-harvest techniques/practices and storage
Improvement of product quality: eco-labelling, reduction of post-harvest losses, value addition
Flexibility to enable seasonal migration (e.g. following stock migration)
Diversify patterns of fishing activities with respect to the species exploited, location of fishing grounds and gear used to enable greater flexibility

LIVELIHOODS
Within sector
Private investment in adapting fishing operations, and private research and development and investments in technologies e.g. to predict migration routes and availability of commercial fish stocks
Adaptation oriented microfinance
Between sectors
Livelihood diversification (e.g. switching between rice farming, tree crop farming and fishing in response to seasonal and interannual variations in fish availability)
Exit strategies for fishers to leave fishing
Risk pooling and transfer
Risk insurance
Personal savings
RISK REDUCTION AND RESILIENCE RESPONSE
Risk pooling and transfer
Social protection and safety nets
Improve financial security
Early warning
Extreme weather and flow forecasting
Early warning communication and response systems (e.g. food safety, approaching storms)
Monitor climate change trends, threats and opportunities (e.g. monitoring of new and more abundant species)
Risk reduction
Risk assessment to identify risk points
Safety at sea and vessels' stability
Reinforced barriers to provide a natural first line of protection from storm surges and flooding
Climate resilient infrastructure (e.g. protecting harbours and landing sites)
Address underlying poverty and food insecurity problems
Preparedness and response
Building back better and post-disaster recovery
Rehabilitate ecosystems
Compensation (e.g. gear replacement schemes)

Source: Poulain, Himes and Shelton, 2018.

Institutional options

Institutional adaptations are key factors for successful adaptation. Gaines *et al.*, (2018) have undertaken an analysis of future climate change and found that improvements in fishery management could offset the negative consequences of climate change (enhancing biomass, catch and profit, compared to business as usual), if current reforms to fisheries were implemented to:

- address current inefficiencies;
- adapt to fisheries productivity changes;
- and proactively create effective transboundary institutions.

Further incorporation of fisheries in national adaptation planning is also fundamental for the success of climate change adaptation in the sector (Poulain, Himes and Shelton, 2018; Hanna, 2010). Mainstreaming can indeed leverage resources and activities associated with existing fisheries (or development) budgets, and therefore can shift entire national and sector development plans along more climate smart pathways.

However, it does raise additional challenges given the difficulty in delivering cross-cutting and cross-sectoral policy and programmes and therefore requires additional success factors, such as:

- the presence of a high-level champion (to push mainstreaming across government); and
- the involvement of strong ministries (i.e. finance and economic planning, rather than environment) to help increase integration (Watkiss, Ventura and Poulain, 2019).

Other institutional adaptation examples include monitoring and awareness raising, to take advantage of the threats and opportunities (new species, new markets) posed by climate change as well as reviewing and learning (as climate risks are evolving) to inform policy and practices over time. This may necessitate public investments in research, best practices sharing, etc.) and to have an iterative cycle of monitoring, reviewing and learning.

Livelihood adaptation

Another key adaptation area is livelihood adaptation within the sector and other sectors. These are market and livelihood adaptation strategies, which respond to climate-induced changes. Examples of these include taking longer fishing trips and shifting gear or diversifying markets and fish products (Poulain, Himes-Cornell and Shelton, 2018). As climate change may particularly impact developing countries in the tropics and small island developing states, reactive and spontaneous private[2] adaptation responses may be difficult due to financial or information barriers. In many cases, livelihood adaptation will necessitate planned support by public institutions to encourage changes. There are also options for diversifying livelihoods between sectors. Tourism is sometimes suggested as an alternative income source for fishing communities, but this can create its own challenges and exacerbate the climate change risk (Watkiss, Ventura and Poulain, 2019).

Risk reduction and management for resilience

There are a number of adaptation options that are focused on reducing and managing risks. These include weather and climate services for fisheries (including early warning systems) as well as opportunities for insurance, risk pooling and risk transfer. For the most vulnerable, there is the potential for targeted support through social protection and shock contingency response funds. The use of alternative ecosystem-based adaptation for coastal protection (e.g. coral restoration and mangrove protection), particularly in tropical countries, is also promoted as an alternative to hard protection (sea walls), and studies show potentially high benefits. In general terms, disaster and emergency preparedness and response has very large benefits in literature (Watkiss, Ventura and Poulain, 2019).

Baticados (Chapter 2, this volume) and Campos and Bagarinao-Regalado (Chapter 3, this volume) identify other examples of institutional, livelihood and risk reduction and management adaptation options in the Republic of the Philippines, with a specific focus

[2] i.e. undertaken by individuals or communities.

on the sardine fisheries (Table 5.4). As with many adaptation options, further discussions and studies are needed to assess their effectiveness.

Table 5.4
Example of selected adaptation strategies in the Republic of the Philippines

FAO adaptation category	Example of adaptive measures	Issues/recommendation
Institutional adaptation (public policies, laws, institutional frameworks, management and planning).	Sindangan, Leon B. Postigo, Jose Dalman, Salug and Manukan municipalities in Zamboanga del Norte observed a monthly three-day fishing ban for all fish species in their municipal waters, following the lunar phase of every new moon. Some processors in the canning industry and commercial fishing companies in Zamboanga City have been practicing "self-regulation" by deferring fishing from November to March due to low fish catch.	Building up their capacities for a co-management arrangement to include climate change adaptive strategies.
	Establishment of bay-wide coastal resource management (CRM) of contiguous municipal waters	Uniformity of law adaption for contiguous municipal waters engaged in bay-wide CRM.
	1. Establishment of MPAs and fish sanctuaries involving resource users; MPA (1 800) database with vital information for CRM as a decision support system, can be seen as a hub to support the fisheries monitoring programme of the Bureau of Fisheries and Aquatic Resources. 2. Participation of resource users as member of Barangay Fisheries and Aquatic Resources Management Councils.	Use of database to promote continuity and connectivity of efforts. Fishing ordinance and regulations in over collection/overfishing is recommended.
	Rehabilitation of the degraded areas for close monitoring	
	Closed season policy (Visayan Sea; Zam-Pen; Tanon Strait).	Include harvest control rules and reference points should be determined for specific fish species and fishing grounds.
	National Stock Assessment Programme fish stocks monitoring.	Use of database for decision-making e.g., closed season policy

FAO adaptation category	Example of adaptive measures	Issues/recommendation
Risk reduction and management for resilience (risk transfer; early warning; risk reduction; preparedness and response).	Coral restoration in reef ecosystems through transplantation, coral sexual propagation and coral juvenile out-plantation, and capacity building activities. Technologies are also being developed to improve restoration and management in support of coral restoration and rehabilitation.	Capacity-building.
	Mangrove reforestation and rehabilitation in carbon sequestration through reforestation efforts and protection of marine waters from encroachment.	Observe science-based protocol in planting mangrove
	Climate forecast that details the probable onset of the event and its likely societal impacts, its magnitude, its duration, etc.; governments could identify the level of risk to its food-producing regions by determining if those regions might be at risk of drought or flood or some other climate-related hazard. The information dissemination should be presented in plain language and drill exercises may be necessary to teach them what to do in case of emergencies.	LGU and concerned parties for adaptive and mitigation planning
	Department of Science and Technology, Philippine Atmospheric, Geophysical and Astronomical Services Administration projections of climate change by region and province	Use for climate change adaptation and disaster risk reduction planning

Source: Baticados (Chapter 3 this volume).

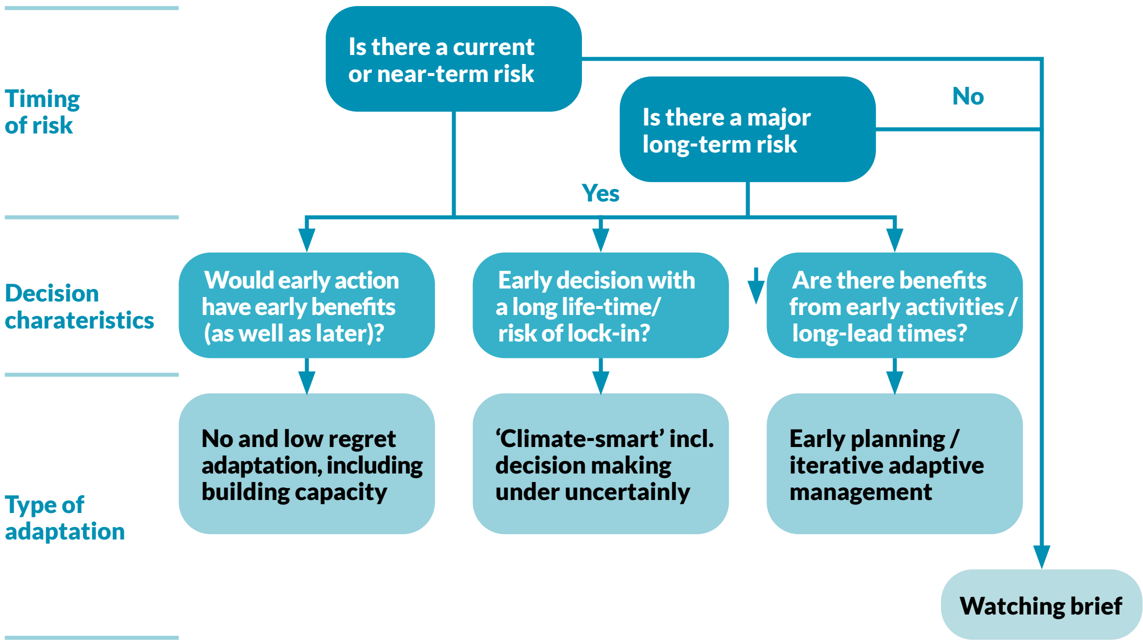
5.5 INTRODUCTION TO ADAPTATION SEQUENCING/TIMING

Some frameworks and tools have been developed to address the challenge associated with decision-making under uncertainty. These include frameworks for early adaptation prioritization and sequencing that are often termed "no or low regret" adaptation frameworks and include a set of interventions as follows:

- Interventions that have benefits in addressing current climate risks. Many of these overlap with current good practice in the fisheries sector.
- Early interventions to ensure that adaptation is considered in decisions that have long lifetimes or lock-in, i.e. long-lived investment that will be exposed to future climate change, such as major infrastructure developments.
- Early adaptation steps for decisions that have long lead times, or early adaptation to start preparing for long-term major climate change (i.e. planning, monitoring, pilots, research) to help inform future strategies as part of iterative adaptive management.

Note that in the national context, all three of the above priorities are needed. These can be presented as an adaptation pathway over time (Figure 5.5) and can be linked to policy cycles.

FIGURE 5.5
Categories of adaptation activities



Source: Watkiss, Ventura and Poulain, 2019.

Once adaptation options have been identified in broad terms, or a shortlist of possible "no or low-regret" options has been identified, it is possible to use appraisal to assess them in more detail (e.g. cost benefit analysis, iterative risk assessment, real option analysis, robust decision making, portfolio analysis) with due consideration of non-monetary and non-market measures, inequities, etc. There is emerging guidance available on the application of these approaches, though to date there has been low application for fisheries and aquaculture (Watkiss, Ventura and Poulain, 2019).

5.6 CONCLUSIONS AND WAY FORWARD

Climate change can pose different risks to the sardine fisheries in the Republic of the Philippines. The objective of this paper is to discuss some of the potential risks and the types of adaptation responses that could be put in place to increase the resilience of the sector in the face of climate change. A wide range of adaptation approaches and tools exist, involving institutional changes, livelihood options and risk reduction and management measures. These measures are briefly introduced in the chapter, taking into account their likely relevance to the Republic of the Philippines' sardine fisheries, or where available, evidence of costs and benefits.

In the Republic of the Philippines, some adaptation options of relevance to the sardine fishery are already in place or being planned under different initiatives, such as the Bureau of Fisheries and Aquatic Resources' Disaster Risk Reduction and Management Strategic Framework (BFAR DRR/M) and the NSMFP 2019 to 2024. The NSMFP recognizes, for instance, the need for climate change impact studies as a high priority for the fishery.

In line with the adaptation decision cycle outlined in this paper and with a view to contributing to the incorporation of climate adaptation considerations into the NSMFP, we recommend that the following steps be addressed during the workshop and beyond:
Identify and agree on the main threats and risks to the sardine fishery, using the best available knowledge, model projections and stakeholder views. The reviews prepared by Campos and Bagarinao, Baticados and Fernandez-Reguera, (Chapter 2, 3 and 4, this volume) are a good starting point for discussions.

For each of the main threats and risks in (1), identify potential adaptation options that would mitigate the risk and increase resilience, including institutional options (e.g. changes in regulatory tools), livelihood adaptations and risk reduction and management mechanisms, when appropriate.

Carry out a preliminary appraisal of the identified options considering, among others:

- the likely benefits and costs, even if qualitative at this stage;
- the existing and expected constraints, barriers and opportunities, particularly related to their implementation;
- the expected effectiveness of the proposed options; and
- the additional issues of importance to the sardine fishery that potentially would be affected (negatively or positively) if the option is implemented. With regard to the latter, it would be a valuable exercise to also identify potential synergies with the existing measures and those discussed under the framework of BFAR DRRM and the NSMFP. The measures identified by Baticados (Chapter 3, this volume) and detailed in Table 5.4 provide good examples.

The above steps would lead to the identification of a shortlist of possible “no or low-regret” options for the fishery. The results of the above analysis and discussions will also provide elements for enhancing ongoing efforts to manage sardine fisheries and also to guide future capacity development interventions regarding fisheries adaptation to climate change.

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These are the proceedings of the national workshop "Risks and Vulnerability of the Sardine Fisheries Sector to Climate and other Non-Climate Processes" held in September 2019 in Quezon City, Republic of the Philippines. The workshop and contributed papers served as an exercise and starting point for the fisheries sector of the Republic of the Philippines and other stakeholders to improve understanding of the framing of climate-related risks and adaption planning, and to deliberate on appropriate management responses and adaptation actions specifically for the sardine fishery. Lessons learned from this exercise may be beneficial in understanding and managing other types of fisheries threatened by climate change.

ISBN 978-92-5-135266-3

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CB7506EN/1/11.21