The 5th Regional Scientific and Technical Committee Meeting
For the SEAFDEC/UN Environment/GEF Project on Establishment and Operation of a Regional System of Fisheries *Refugia* in the South China Sea and the Gulf of Thailand

16-17 March 2022
(08:30 – 12:00 am, UTC+7)
Zoom platform

INDICATORS FOR SUSTAINABLE MANAGEMENT OF FISHERIES REFUGIA

Executive Summary

Indicators play an essential part in the communication of scientific results to decision-makers. Many countries develop indicators to support effective decision-making and policy-setting at every stage of the decision-making cycle - during problem identification, policy formulation, implementation, or policy evaluation. This paper reflects the needs of indicators by six implementing countries to support the sustainable management of fisheries refugia. The long-term objectives of the indicators are aimed to

1. maintain the fish stock and critical habitats,
2. satisfy the fishing community and social needs now and future,
3. put in place an effective management system.

The indicators defined by regional fisheries refugia experts are based on a structural framework for enhancing the sustainable management of fisheries refugia, including twelve targets under four dimensions: social, ecosystem, economic, and governance. Climate change impacts on the ecosystem are considered a critical cross-cutting dimension in the structural framework consisting of 3 sub-dimensions. In addition, the indicator related to gender aspects is included in the social dimension. It is expected that a total of 15 targets with 44 criteria and 94 indicators specified as operational tools will practically guide the government in effectively managing fisheries refugia for long-term sustainability in Southeast Asia and other regions.

Actions by the RSTC

- The Regional Scientific and Technical Committees are invited to provide comments on the 1st Draft of Indicators for Sustainable Management of Fisheries Refugia,
- The Committees are also requested for endorsement as it is or as amended based on the comments during the session for further submission to the Project Steering Committee for consideration.

Southeast Asian Fisheries Development Center

United Nations Environment Programme

Global Environment Facility

Establishment and Operation of a Regional System of Fisheries *Refugia* in the South China Sea and Gulf of Thailand

INDICATORS FOR SUSTAINABLE MANAGEMENT OF FISHERIES *REFUGIA*

SEAFDEC/UNEP/GEF
Fisheries *Refugia*
2022

Southeast Asian Fisheries Development Center

United Nations Environment Programme

Global Environment Facility

First published in Phrasamutchedi, Samut Prakan, Kingdom of Thailand in XXXX 2022 by the SEAFDEC/UNEP/GEF Fisheries Refugia Project, Training Department of the Southeast Asian Fisheries Development Center

SEAFDEC/UNEP/GEF
Project Co-ordinating Unit
Training Department
Southeast Asian Fisheries Development Center
Postal Address: P.O.Box 97, Phrasamutchedi, Samut Prakan, Kingdom of Thailand
Tel: (66) 2 425 6100
Fax: (66) 2 425 6110
https://fisheries-refugia.org

For citation purposes this document may be cited as:

SEAFDEC, 2022. Establishment and Operation of a Regional System of Fisheries Refugia in the South China Sea and Gulf of Thailand, Indicators for Sustainable Management of Fisheries Refugia. Southeast Asian Fisheries Development Center, Training Department, Samutprakarn, Thailand. 34p.

INDICATORS FOR SUSTAINABLE MANAGEMENT OF FISHERIES *REFUGIA*

THE ORIGIN OF THIS WORK

This paper grew out of a three-day workshop on sustainable management indicators for long term Fisheries Refugia approaches by small expert groups from six Southeast Asian Countries, members of the GEF/UNEP/SEAFDEC project on "Establishment and Operations of a Regional System of Fisheries Refugia in the South China Sea and the Gulf of Thailand" initiated from 2016 to 2022.

The workshop was held at A-One The Royal Cruise Hotel, Pattaya City, Chonburi Province, Thailand, from 9-11 September 2019. The participants, identified here by their institution, were:

- Ouk Vibol, Department of Fisheries Conservation, Fisheries Administration, Cambodia
- Leng Sy Vann, Department of Fisheries Conservation, Fisheries Administration, Cambodia
- Joni Haryadi, Agency for Marine and Fisheries Research and Human Resources, Ministry of Marine Affairs and Fisheries, Indonesia
- Ir. Ngurah N. Wiadnyana, Agency for Marine and Fisheries Research and Human Resources, Ministry of Marine Affairs and Fisheries, Indonesia
- Haryati binti Abdul Wahab, Resource Management Division, Department of Fisheries, Malaysia
- Ryon Siow, Fisheries Research Institute, Malaysia
- Joeren S. Yleana, Bureau of Fisheries and Aquatic Resources, Philippines
- Valeriano M. Borja, National Fisheries Research and Development Institute, Philippines
- Nguyen Thanh Binh, Directorate of Fisheries, Viet Nam
- Nguyen Van Minh, Directorate of Fisheries, Viet Nam
- Praulai Nootmorn, Department of Fisheries, Thailand
- Kumpon Loychuen, Department of Fisheries, Thailand
- Weerasak Yingyuad, Southeast Asian Fisheries Development Center, Thailand
- Somboon Siriraksophon, Fisheries Consultant, Thailand

The workshop was a brainstorming session moderated by Fisheries Consultant Somboon Siriraksophon, as a Project Manager employed by the Project. Inputs were also based on individuals and six countries responsible for fisheries, namely Cambodia, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam. The questions came to our minds on how the Refugia approach subsidizes the sustainable development in fisheries. Nevertheless, what kinds of information and indicators we would need to guide ourselves toward a sustainable world in the context of the fisheries refugia approach.

This paper also considers the progress works of all regional experts from six participating countries on the establishment of fisheries refugia. The challenges, issues, and achievements facing each country are the essential lessons learned and information for coloring the paper.

ACRONYMS

ASEAN	Association of South East Asian Nations
CBD	Convention of Biological Diversity
CCRF	Code of Conduct for Responsible Fisheries
CRM	Coastal Resource Management
EA	Ecosystem Approach
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
GEF	Global Environment Facility
ICZM	Integrated Coastal Zone Management
IUCN	International Union for Conservation of Nature and Natural Resources
IUU	Illegal, Unreported, and Unregulated fisheries
MPI	Multidimensional Poverty Index
MSP	Marine Spatial Planning
MTL	Mean Trophic Level
OEA	Open Access Equilibrium
PPR	Primary Production Requires
PSR	Pressure-State-Response
SEAFDEC	Southeast Asian Fisheries Development Center
UN	United Nations
UNCLOS	United Nations Convention of the Law of the Sea
UNEP	United Nations Environment Programme
WCS	World Conservation Strategy

Table of Contents

CHAPTER 1: INTRODUCTION

1.1 IMPORTANCE OF INDICATORS

> *If we could first know where we are, and whither we are tending, we could better judge what to do, and how to do it. (Abraham Lincoln, speech to the Illinois Republican state convention, June 16, 1858).*

Intuitively, we all use indicators to monitor the complex systems we care about or need to control. Indicators are part of everyone's life. Indicators are also a necessary part of the stream of information we use to understand things, make decisions, and plan our actions. For example, fishers scan the sky for weather sea condition fronts before deciding to leave port for fishing. We have many words for indicator - sign, symptom, signal, tip, clue, grade, rank, data, pointer, dial, warning light, instrument, measurement, a reference point.

The Convention of Biological Diversity (CBD) adopted the concept to understanding trophic interactions and how fisheries affect, using the mean trophic level (MTL) and primary production requires (PPR) as ones of the indicators for the management of sustainable fisheries exploitation (Hornborg. *el.al*., 2013).

In terms of the environmental health indicators, which aim to give people the idea of whether their environment is getting better or worse, an overview of six analytical frameworks or models was defined by Julie *et al*., 2004. They described the scientific aspects of indicator establishment by including frameworks and criteria that apply to establishing a core indicator list for environmental health in Fander, Nothern Belgium.

In fisheries aspects, FAO (1999) stated that indicators aim to enhance communication, transparency, effectiveness, and accountability in natural resource management. Indicators assist in the process of assessing the performance of fisheries policies and management at global, regional, national, and sub-national levels. They provide a readily understood tool for describing the state of fisheries resources and fisheries activity and for assessing trends regarding sustainable development objectives. In measuring progress towards sustainable development, a set of indicators should also stimulate action to achieve **sustainable development**.

1.2 SUSTAINABLE DEVELOPMENT CONCEPT AND FISHERIES SUSTAINABILITY

The concept of sustainable development has emerged as a key guiding principle and action agenda for all forms of environmental management, economic development, and social justice at international, regional, national, sub-national, and local levels. The 'triple bottom line' of sustainability concept (Elkinton, 1997) has revolutionized the way we see and interact with the world and each other, as shown in **Figure 1**. It attempts to set a course for an increasingly innovative future based on conservation and protection, wise resource use, social equity, economic growth, and stability. The concept emerged in the late 1980s with groundbreaking international reports such as Our Common Future and the early 1990s with the UN Declaration on Environment and Development negotiation and its product: Agenda 21 (UN, 1993). Sustainability implies that all socio-economic (human-based) systems and ecological (natural-based) systems should remain in a healthy and viable state so that benefits can flow to current and future generations. This includes the orientation of development activities within the carrying capacity of the natural environment to ensure ongoing resource availability and environmental services. Management for sustainability should, therefore, consider integrated approaches, ecosystem scales, and socio-economic considerations. Initially, ideas of sustainability were promoted when the effects of environmental degradation became increasingly visible across the globe. Poverty, population pressure, unequal resource distribution, and trade were the base causes of environmental degradation in developing countries, which required a new development approach to create sustainable economies.

Sustainable development was also viewed as entirely relevant to the developed nations, with the concept highlighting integrated aspects of conservation and economic growth, technology and information transfer, energy, food supply, security, transport, and pollution control.

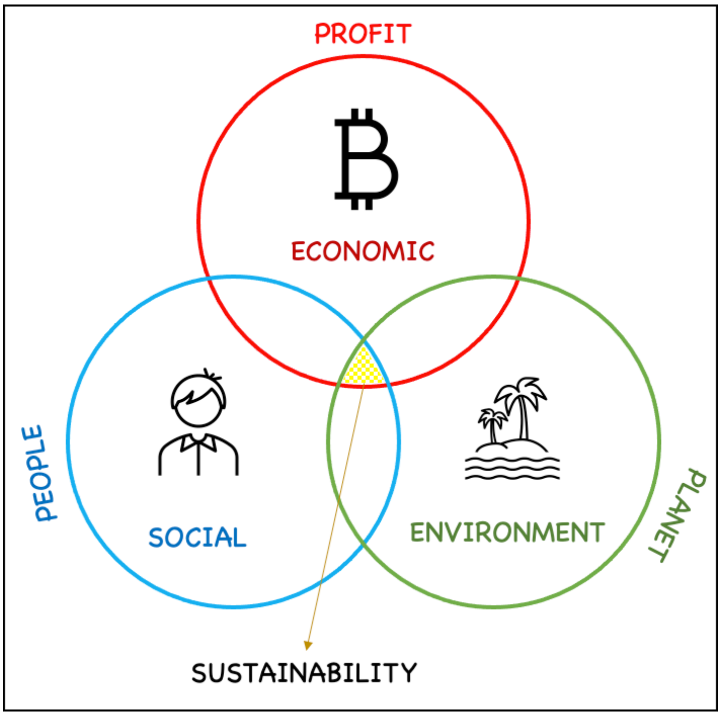


Figure 1: Triple Bottom Line of Sustainable Development Concept

For development to be sustainable, it must take account of social and ecological factors, as well as economic ones, of the living and non-living resource base, and the long term as well as short-term advantages and disadvantages of alternative actions (World Conservation Strategy (WCS)(IUCN 1980).

The concept of sustainability has dramatically altered the fisheries sector. Over the last century, activities have intensified from a local scale to a global market industry that employs millions and is a source of income and food for many nations. After modernization and industrialization of the fisheries sector, distant water fleets have been able to circumnavigate the globe in sourcing fisheries stocks, often with severe consequences for offshore species or conflicts with localized and community-based fisheries. In addition, with increasing coastal state control and rights over living marine resources after the signing of the United Nations Convention of the Law of the Sea in 1982, the capacity of fishing effort for domestic-based fisheries has dramatically increased in national EEZs, leading to further pressures on the stocks. As a result, marine living resources are under stress, with many showing signs of degradation and collapse due to overcapacity and destructive fishing practices. Current statistics display that the global capacity of the ocean to produce wild harvests is at its maximum sustainable limit. In addition, the broader ecosystems have been detrimentally affected, especially species associated with or dependent on target stocks. Bycatch and habitat degradation remain two crucial issues for modern fisheries management. The increased impact of Illegal, Unreported, and Unregulated fisheries (IUU) further stresses the global supply and the viability of marine ecosystems. Agenda 21, Chapter 17, provides important challenges and opportunities for nation states in the implementation of policies related to ocean and coastal management. The policy has oriented the concept at a strategic level but requires applying sustainability concerns at an operational level. The current challenge for the fisheries sector is to interpret and practically apply the concept of sustainability into fisheries practice. In other words, developing sustainability indicators in fisheries contexts are urgently needed, as a valuable and practical process, to incorporate ecosystem management and precautionary concerns into fisheries management operations.

1.3 INDICATORS FOR FISHERIES SUSTAINABILITY

Indicators have increasingly been seen as a valuable tool for 'building in' sustainability into various sectors, with efforts to pursue this process with fisheries (FAO, 1999). Indicators fulfill multiple roles in fisheries systems and can be adapted to a particular use or set of users, including public education, performance assessment, meeting legislative and policy goals, broadening the management base, increasing participation and coordination, management certification, and environmental protection reporting. The FAO guidelines on indicators for sustainable development of marine capture fisheries were drafted in 1999. Later it was adopted by their member countries in the same year to support the implementation of the Code of Conduct for Responsible Fisheries (CCRF). The guidelines provide general information on the sustainable development of fisheries to clarify why a system of indicators is needed to monitor the contribution of fisheries to sustainable development. The guidelines also provide information on the type of indicators and related reference points required. However, it is recognized that it is difficult to generalize. There is a need to agree on common conventions for joint reporting at the national, regional, and global levels, particularly international fisheries, or transboundary resources.

In Southeast Asia, fisheries development has been confronted with various concerns, notably over-exploitation of the limited resources, which results in the degradation of the fishery resources. Moreover, excessive fishing capacity, use of irresponsible fishing practices, conflicts among the various stakeholders, and lack of an appropriate regulatory system for fisheries are the multiple factors that contribute to the deterioration of the fishery resources. To address such concerns, the governments of the countries in the region have been promoting sustainable fisheries resources management over the past three decades. The global Code of Conduct for Responsible Fisheries (CCRF) developed by FAO as well as by the Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region adopted during the ASEAN- SEAFDEC Millennium Conference on "Fish for the People" in November 2001 has been used as frameworks in the Southeast Asian countries' efforts towards sustainable fisheries management. In addition, in collaboration with the ASEAN member states, the Southeast Asian Fisheries Development Center (SEAFDEC) published in 2003 the Regionalization of the Code of Conduct for Responsible Fisheries (RCCRF) in Southeast Asia. Later in 2006, the Supplementary Guidelines on Co-management Using Group User Rights, Fishery Statistics, Indicators and Fisheries Refugia was published mainly to substantiate the afore-mentioned Regional Guidelines. The supplementary guidelines on the Use of Indicators for Sustainable Development and Management of Capture Fisheries in Southeast Asia were achieved through consultations and after several pilot-testing activities in selected countries in the ASEAN region. Considering that the Guidelines specify the need to develop the National System to Use Indicators for marine capture fisheries management, ASEAN Member States strongly requested to systematically establish the most critical and proper fisheries indicators and standards for fostering sustainable fisheries management in the respective country.

CHAPTER 2: UNDERSTANDING FISHERIES REFUGIA CONCEPT

2.1 NATURE OF FISHERIES AND ADAPTIVE MANAGEMENT NEEDS

Considering the nature of fisheries in the region, which is mainly characterized as tropical small-scale multi-species/multi-gear fisheries, the use of indicators for fisheries management in an adaptive manner is seen to be more practical and easily understood and supported by the stakeholders. Adaptive management is a paradigm shift from a predictive approach to an adaptive strategy. Under a broad co-management concept, adaptive management is an approach where fishery managers react on indicators to assess fisheries, resources, and eco-system instead of classical stock assessment (e.g., MSY and MEY). Adaptive management is a process to achieve management objectives and a learning process among interested stakeholders about fisheries or systems being managed to adopt policies and management frameworks to be more responsive to future conditions. The backbone of an excellent adaptive fisheries management system lies in a good data and information system in which we apply to the sustainable management of fisheries refugia approach.

2.2 COMPARISON WITH OTHER ECOSYTEM APPROACHES

The concept of fisheries refugia has been developed by the Fisheries Component of the UNEP/GEF Project Entitled "Reversing Environmental Degradation Trends in the South China Sea and the Gulf of Thailand" (UNEP/GEF SCS Project) in collaboration with the SEAFDEC for the development of a regional system of fisheries refugia. The Fisheries Refugia approach is based on the "ecosystem approach (EA)" concept like many existing approaches such as Marine Spatial Planning (MSP), Coastal Resource Management (CRM), Co-management, and Integrated Coastal Zone Management (ICZM). Fisheries refugia are developed in parallel by different user groups with specific management interests. Fisheries refugia share many of the same principles and have many commonalities with other approaches, but management focus or coverage can be different and support each other. In practice, fisheries refugia can incorporate conventional fisheries management and overlaps with co-management, MSP, and ICZM, as shown in **Figure 2**.

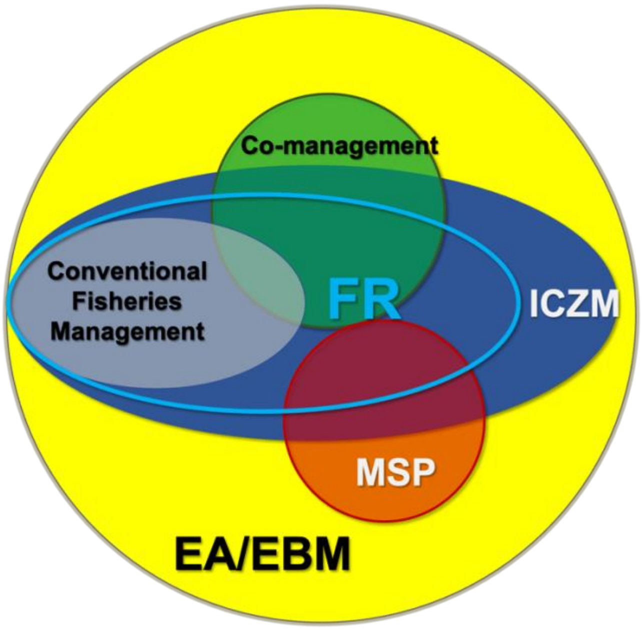


Figure 2: Fisheries Refugia and Other Existing Approaches for Sustainable Development

2.3 FISHERIES REFUGIA CONCEPT

Fisheries Refugia (Paterson *et al*., 2012) was developed as a novel fisheries resource management approach to the identification and designation of priority areas in which to integrate fisheries and habitat management in the context of maintaining fish stock and critical habitats as satisfying the fishing community, social needs now and futures. The fisheries refugia approach needs a good platform for building partnerships, enhancing communication and engagement of stakeholders, finding local and scientific-based knowledge, and putting in place an effective integration of fisheries and habitat management. In some cases, the management of fisheries refugia may include the transboundary fish stock or shared stocks issues in which cooperation among relevant states is needed to take into accounts.

In the South China Sea and the Gulf of Thailand Sub-regions, against the general background of uncertainty and complexity associated with the development of fisheries refugia, there is a need to develop robust and workable solutions to involve stakeholders in establishing and managing refugia. An emerging appreciation of the diverse traditions and cultures in the region and the vital role of small-scale, coastal, and subsistence fisheries has recently provided an impetus for the development of fisheries refugia approaches to stakeholder participation in the management of fisheries at all levels.

The concept supports the Regional Guidelines for Responsible Fisheries in Southeast Asia with emphasis on item 7.6.4 ADD. 1 on Responsible Fishing (SEAFDEC, 2003), which states that in terms of taking appropriate action to ensure that fishing gear, methods, and practices that are not consistent with responsible fishing are phased out and replaced with more acceptable alternatives: "*States should consider area or seasonal closure to protect critical stages of the life cycle of fisheries resources*." In addition, the concept also builds upon item 7.6.9 of the Regional Guidelines on Wastes, Discards, and Ghost Fishing, which states that in terms of taking appropriate action to minimize waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species, in particular, endangered species: "*States should strongly implement management measures such as closed areas and seasons in critical habitats (e.g., coral reefs, seagrass beds, mangrove areas, etc.) which are important for sustaining fish stocks*."

The concept of natural refugia is well developed in the fields of terrestrial ecology and wildlife management. For instance, spatial controls that recognize the potential "source-sink" nature of hunted systems and protect natural refugia often effectively avoid wildlife over-exploitation when biological data and enforcement capabilities to regulate harvests are limited. In the context of fisheries, natural refugia arise from the interaction of the spatial dynamics of the population, oceanographic features, fish behavior, and fishing effort dynamics. The fisheries refugia approach can complement conventional fisheries management measures, such as effort or gear restrictions. It should be a priority consideration in the ASEAN region when fisheries are subject to intense and unmanageable fishing pressure. They may also be used to separate potentially conflicting uses of coastal and marine habitats and their limited resources. However, the effectiveness of fisheries refugia will largely depend on the selection and appropriate use of fisheries management measures within the refugia area, and at the most general level, the process of establishing fisheries refugia must consider the:

- Life-cycle of the species for which refugia are being developed,
- Type(s) of refugia scenarios(s) that relate to the species for which refugia are being developed,
- Location of natural refugia and appropriate sites for the establishment of [artificial] refugia, and
- National and regional level competencies in using fisheries management measures and spatial approaches to resource management and planning.

Fisheries Refugia in the ASEAN context is defined as: "Spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use." There is a general commonality of understanding that fisheries refugia relate to specific areas of significance to the life-cycle of particular species. Fisheries refugia may be defined in space and time and protect spawning aggregations, nursery grounds, and migratory routes**. Figure 3** shows a generalized life-history triangle for fished species, highlighting the problems of growth and recruitment overfishing, which are reflexed the requirements to protect juvenile and spawning refugia.

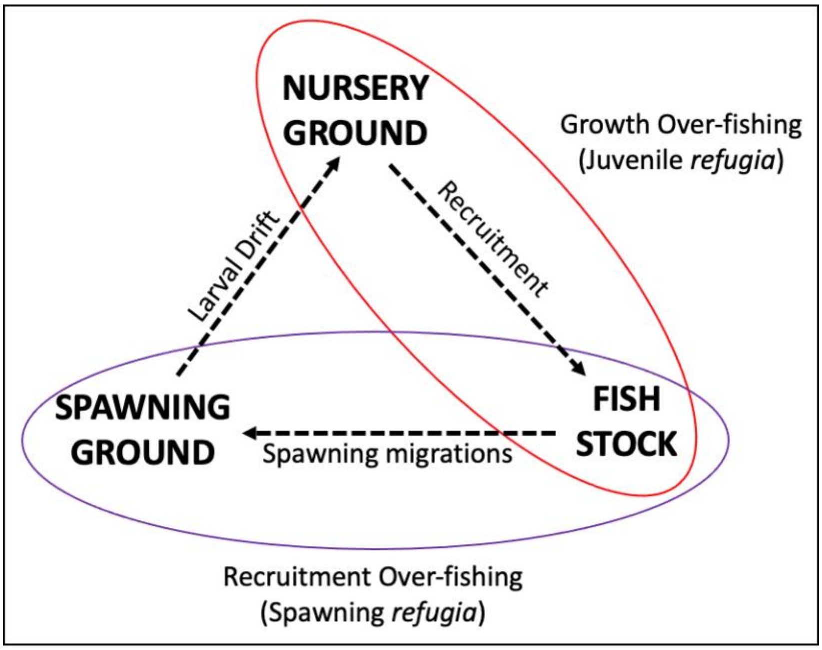


Figure 3: Life-history triangle highlighting the need for refugia to protect the recruitment

Therefore, the promotion and use of the fisheries refugia concept in the ASEAN region is aimed at improving the use of spatial approaches to fisheries management for the sustainable use of fisheries. The specific fisheries management problems in the ASEAN region that fisheries refugia will assist in resolving to include:

- The capture of juveniles – an action focused on reducing the risk of growth over-fishing due to young recruits to the fishery being caught before they grow to optimal market size, or a size at first capture less than that required to maximize yield (or value) per recruit,
- The capture of spawning stock in spawning areas at the time of spawning – an action focused on reducing the risk of recruitment over-fishing due to adult stock being reduced to the extent that recruits are insufficient to maintain commercial fish stocks,
- Use of inappropriate fishing gears and practices,
- Poor management of fish habitats, particularly spawning and nursery areas, and
- Conflicts among resource users – such as those between small-scale and large-scale fisheries.

While recognizing that the overall goal associated with the fisheries refugia approach is to improve the service of spatial approaches to fisheries management for sustainable use of fish stocks and maintenance of habitats, objectives relating to fisheries refugia should be developed with stakeholder engagements. In defining such objectives, ASEAN Member States must consider the **objective-related indicators** to support evaluating the performance of fisheries refugia. Specific objectives may be drawn from the following [non-exhaustive] list and should be defined in terms of temporal and spatial scales:

- Safeguarding of spawning and nursery areas and commercial species within these areas at critical stages of their life cycles,
- Enhancement of fisheries resources and their habitats,
- Prevention of habitat degradation and commercial extinction of important fishery species,
- Improved coordination between fisheries and environmental agencies and organizations,
- Enhanced use of zoning in fisheries management,

- Improved incorporation of species-specific life-history characteristics in fisheries management systems,
- Improved understanding amongst stakeholders, including fisherfolk, scientists, policymakers, and fisheries managers of ecosystem and fishery linkages, and
- Promotion of the role of refugia in enhancing the resilience of fisheries systems.

CHAPTER 3: INDICATORS FOR MANAGING FISHERIES REFUGIA

3.1. LONG-TERM OBJECTIVES

From the brainstorming among regional experts help in September 2019, the objectives for management of fisheries refugia should reflect on healthy and sustainability align with the Triple Bottom Line of Sustainable Development Concept. The long-term objectives for development of the indicators for management of fisheries refugia are defined as to:

a) **Maintain the fish stock and critical habitats**: The successful maintaining or enhancing fish stocks requires harvest controls but also demands and attention to human impacts on the habitat. Reducing exploitation alone on the stock being restored will not be effective if critical habitat has disappeared.

b) **Satisfy fishing community, social needs now and futures**: Taking the time and effort to understand your community well before embarking on a community effort will pay off in the long term. A good way to accomplish that is to create a community description -- a record of your exploration and findings. It's a good way to gain a comprehensive overview of the community -- what it is now, what it's been in the past, and what it could be in the future.

c) **Put in place on effective management system**: Available evidence suggests that the regions without assessments of abundance have little fisheries management, and stocks are in poor shape. Increased application of area-appropriate fisheries science recommendations and management tools are therefore needed for sustaining fisheries in places where they are lacking.

3.2. DEVELOPING THE FRAMEWORK

As indicators play an essential part in the communication of scientific results to decision-makers. Many countries develop indicators to support effective decision-making and policy-setting at every stage of the decision-making cycle - during problem identification, policy formulation, implementation, or policy evaluation. In developed countries, many fisheries are assessed and evaluated using models of growing complexity that require data. Model results are often very complex, and their presentation may vary significantly between models. Comparison with many developing countries, because the costs of data collection and analysis for these models may be relatively high, it is not feasible to collect all the information required, and a set of indicators can simplify the evaluation and reporting process. Hence, the finding indicators need to be presented simply and understandably.

Rapport and Friend (1979) indicated the good indicators could be oriented to reflect better the pressures of human activities, the state of human and natural systems, and society's responses to the changes in those systems as called a pressure-state-response (PSR). The PSR model highlights these cause-effect relationships and helps decision-makers, and the public see environmental, economic, and other issues as interconnected. In this guideline, developing the indicators for sustainable management of fisheries refugia considers a structural framework representing all the relevant dimensions of sustainable development, *e.g*., economic, social, environmental (ecosystem/resource), and institutional/governance.

As noted above, the SCS is a global hotspot of marine biodiversity subjected to high and increasing levels of small-scale fishing pressure and other threats. Various fisheries management reforms are required to fashion a sustainable future for the fisheries of this marine basin. As such, it is important that the refugia initiative is not viewed as a proposed ‘panacea’ to the fisheries problems of Southeast Asia, rather one of a series of complementary management strategies being promoted regionally, including efforts to curb the high and increasing levels of fishing pressure. However, given the high rates of habitat loss and the high levels of community dependence on small-scale fisheries, it is imperative that efforts to operate the regional fisheries refugia system be sustained. Accordingly, the regional experts defined a structural framework for enhancing the effective sustainable management of fisheries refugia into twelve targets under four dimensions as shown in Figure 4.

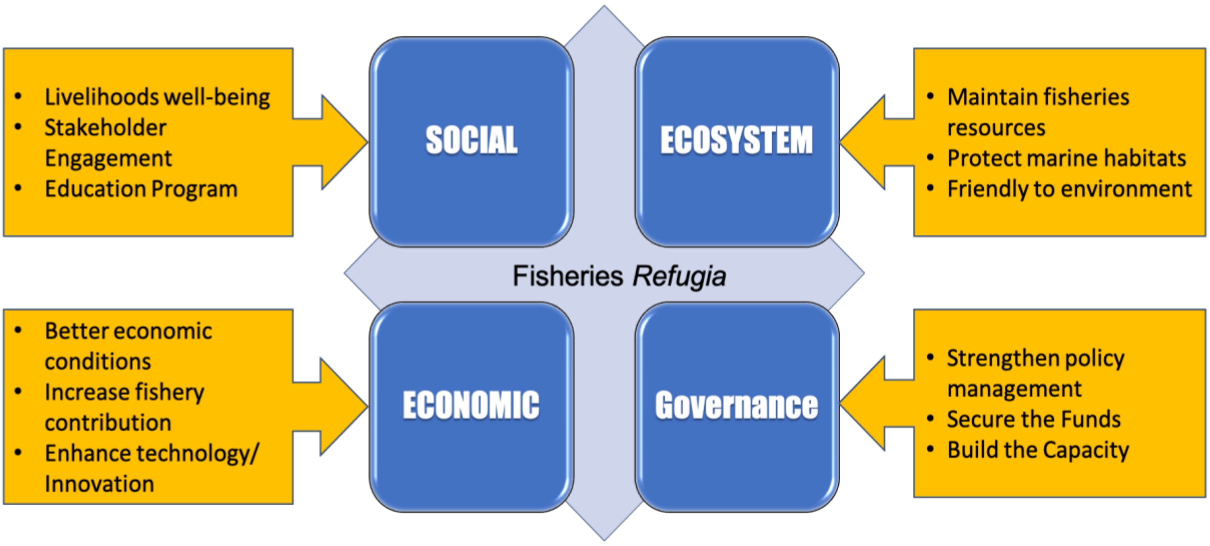


Figure 4: Structural framework for enhancing the effective sustainable management of fisheries refugia

a) **Ecosystem Dimension**: Managing a complex ecosystem to balance delivery of all its services is at the heart of ecosystem-based management. But how can this balance be accomplished amidst the conflicting demands of stakeholders, managers, and policy makers? In marine ecosystems, several common ecological mechanisms link biodiversity to ecosystem functioning and to a complex of essential services. As a result, the effects of preserving diversity can be broadly beneficial to a wide spectrum of important ecosystem processes and services, including fisheries, water quality, and recreation. In this guideline, we defined the ecosystem into three sub-dimensions: 1) fisheries resources, 2) marine habitats, and 3) marine environment. To maintain the ecosystem health, we need to maintain fisheries resources, protect the marine habitats and friendly to the marine environment.

b) **Governance Dimension**: Good governance is fundamental to ensuring the equitable and sustainable management of fisheries and to facilitate policy change. To improve fisheries governance, further analysis of institutional arrangement of fisheries governance is needed to better understand how different structures impact policymaking. In particular, it would be interesting to investigate how institutions can facilitate increased co-ordination and coherence between policies for all the sectors using marine resources. For effective policy creation, change, and implementation, countries require a governance process that integrates information on the impacts of existing policies and the views of a wide range of stakeholders collected by institutions that can respond to the specific context of individual fisheries (Delpeuch *et.al.*, 2019). The main objectives of this dimension are strengthening governance and institution capacity as well as strengthening the policy management and securing the fund for sustainability in managing fisheries refugia.

c) **Economic Dimension**: The capture fisheries have played an important role to national economies among ASEAN countries, particularly as a source of foreign exchange earnings, an employment creator and income generator, as well as in food and nutrition security. It was also recognized that the region's contribution to global fishery production has gradually increased from 5% in 1950 to 21.1% in 2014 (FishStatJ, 2016). Considering the economic sustainability refers to practices that support long-term economic growth without negatively impacting social, environmental, and cultural aspects of the community. It can refer either to the continued success of an economy over time or more recently to the way an economy operates in a sustainable manner, protecting social and environmental elements. How can we know the economic sustainability? The guideline defined economic dimension into three sub-dimensions that we need to know as follows: 1) economic health/condition, 2) economic/fisheries production, and 3) driving innovation and transforming fisheries.

d) **Social Dimension**: Social or humans and its relation to the marine ecosystem are at the core of the fisheries refugia approach and a "human dimension" for this approach needs to be understood, analyzed, identified, and implemented. Implementation of ecosystem approach like fisheries refugia without consideration of socio-cultural, economic, political and institutional dimensions is nowadays regarded as incomplete, delivering only partial and insufficient achievements that the approach aims to generate. In addition, failure to consider human dimensions risks producing or reinforcing social inequalities with marginal groups, enhance conflicts and distrust hindering collaboration, ignoring local values, knowledge and skills essential for particular contexts, striping customary social norms, fostering unemployment, depriving individual and collective identities, altering socio-cultural relations and social capital; all of them critical for human well-being and the associated exploited marine ecosystems. We defined three sub-dimensions, to ensure and assess the wellbeing of fishing communities as follows: 1) livelihood conditions, 2) stakeholder engagements, and 3) educational programs.

Climate change impacts and gender mainstreaming aspects are considered as key cross-cutting dimensions that we include in the frameworks particularly the later one we align with the SEAFDEC Gender Strategy (SEAFDEC, 2019) and GEF Policy Guidance on Gender Equality (GEF, 2017). Nevertheless, the focus of climate change impacts is to ecosystem only, not covering the impacts to other social, economic, and governance dimensions.

3.3 SPECIFYING CRITERIA AND INDICATORS

At the fishery level, indicators provide an operational tool in fisheries management as a bridge between objectives and management action. For example, an indicator such as an estimate of current biomass from a stock assessment model may feed into a decision rule that specifies next year's management measures or other input-output controls. Indicators may also be used to trigger a more general management response, such as achievement with respect to a more integrated coastal management plan. Based on the defined fisheries refugia structural frameworks, the criteria and indicators are specified as shown in **Table 1-5.**

Table 1: Specified criteria and Indicators of the **Ecosystem Dimensions** for fisheries refugia approach

SUB-DIMENSIONS	CRITERIA	INDICATORS	UNITS/REF
Fisheries Resources	Abundance stock / Distribution / Fishing Effort	Biomass Estimation	**App.01**
		Level of MSY	**App.02**
		Level of MEY	**App.03**
		Level of CPUE (weight/unit effort)	ton or kg
		CPUA (product wieght/Area)	ton or kg
		Catch landing	Ton or kg
	Biological Parameter	Length at first capture (Lc)	**App.04** cm or mm
		Length at first mature (Lm)	**App.05** cm or mm
		Sex ratio	Ratio of male to female
		Spawning Potential Ratio (SPR)	**App.06**
		Length frequency	cm or mm

SUB-DIMENSIONS	CRITERIA	INDICATORS	UNITS/REF
		Exploitation rate	**App.07**
		GSI (Gonadosomatic Index)	**App.08**
	Species composition / Catch structure	Percentage of dominance species	%
		Number of species	Individual(s).
		Main economic/commercial species	%
		Bycatch Composition	%
Habitat (mangrove, coral, seagrass, and other critical habitats)	Health/condition/ Area	Size Coverage	%
		Habitat Health Index	**App.09**
		Target habitat density (IUCN reference)	**App.10**
Environment	Pollution	Standard Water Quality (e.g. COD, BOD)	**App.11**
	Eutrophication	Phytoplankton Abundance	**App.12** (monitoring)
		Phosphate, Nitrate Concentration (Nutrient loading)	**App.13** (monitoring)
	Anthropogenic (Human activity)	Coastal reclamation area	hectare or Km^2
		Level of maritime activity (If appropriated)	**N/A**
	Erosion	Level and distribution of sedimentation (If appropriated)	**N/A**
		Loss of area/habitat	hectare or Km^2

Table 2: Specified criteria and Indicators of the **Social Dimensions** for fisheries refugia approach

SUB-DIMENSIONS	CRITERIA	INDICATORS	UNITS/REF
Livelihoods	Choice of Occupation	Number of option/ Occupation/ work (Alternative, Permanent work, Subsistence work)	Number
	Fish consumption	Fish consumption per capita per year	**App.14**
	Nutrition	% Animal protein (if appropriate)	%
Stakeholder Participation (Indigenous People, Gender, etc.)	Participation	Ratio of number of participations (gender and IP)	%
	Local Organization	Number of organizations,	Number
		Number of Best practices applied	Number
	Networking	Number of networking	Number
		Type /way of direct or indirect communication	Number
		Number of agreements	Number
Education (Local knowledge, Local wisdom)	Awareness program (e.g. information center, information education campaign (IEC))	Number of information center or similar.	Number
		Number of consultations	Number
		Number of best practices	Number
		Number of awareness program	Number
		Number of understandings by stakeholder	Number

SUB-DIMENSIONS	CRITERIA	INDICATORS	UNITS/REF
	Capacity building	Number of training/Extension	Number

Table 3: Specified criteria and Indicators of the **Economic Dimensions** for fisheries refugia approach

SUB-DIMENSIONS	CRITERIA	INDICATORS	UNITS/REF
Economic Condition (to community)	Poverty incident	Poverty Index, Income Poverty Multidimensional poverty index	**App.15**
	Capital accessibility	Number of financial accessible	Number
	Income	Income per household	income/year
Fisheries Production, Fishing Efforts	Contribution of target species and Availability	Value of contribution or production	ton(s), metric ton(s)
Innovative Fisheries Technology	Effectiveness fishing gear	level of CPUE	**App.16**
	Cost effectiveness	Cost reduction, time, human power	**App.17**
	Environment friendly (Green technology)	Reduce of fuel consumption	**App.18**
		Reduce bycatch	**App.19**
	Investment	• Number of investments • fishing fleet, • processing, • ship builder • management tools/software	• Number • Number • Number • Availability • Availability
		New domestic products	Number

Table 4: Specified criteria and Indicators of the **Governance Dimensions** for fisheries refugia approach

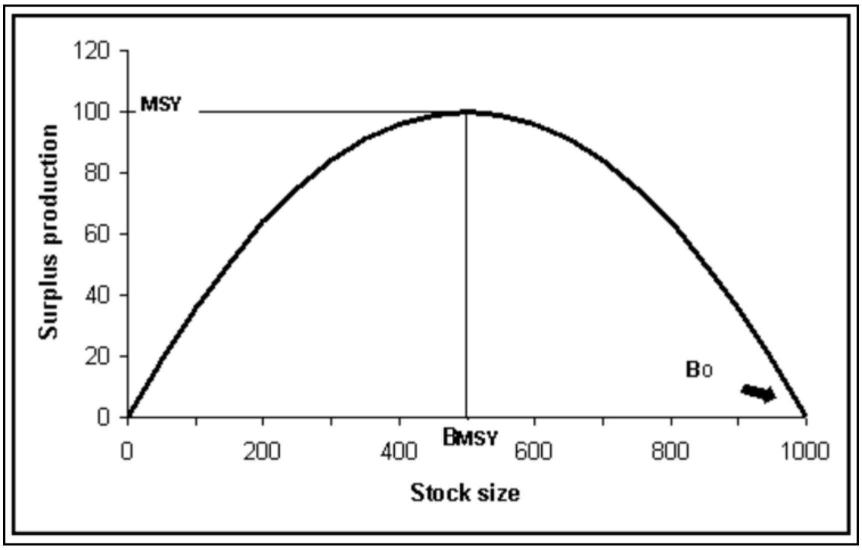
SUB-DIMENSIONS	CRITERIA	INDICATORS	UNITS/REF
Fisheries management policy (Fishing/User Right, Precautionary approaches/Science -based management, and Synergistic Way/Strategy)	Legal framework	Number of law and regulation	In place
	Harvest strategy/ Limit of fishing effort	Fishing closure by area and seasonal closure, Zoning	hectare or Km^2 Days/months
		Number of Input control (Number, mesh size, length of fishing gear, Licensing control, Capacity (e.g. Gross tonnage, horsepower, etc.)	**App.20**
		Number of output control (TAC, Quota, Target species)	**App.21**
	Fisheries management plan/ strategy/ framework	Available/not available	
		Management plan of Fisheries refugia in place,	Reformed
		Habitat rehabilitation, protection and stock enhancement.	Adopted
	Efficiency fishing gear	Length limit (e.g. crab fishery)	cm or mm

SUB-DIMENSIONS	CRITERIA	INDICATORS	UNITS/REF
Stakeholder Cooperation/Coordination (Regional / national levels)	Management mechanism	Management board/ committee, transboundary committee, RPOA for refugia in place	Established Approved
		Linkage to the existing management/conservation framework (e.g. MPAs)	Established
Enforcement	Coordination mechanism	Inter-agency coordination in place, Number of joint operations	Established Number
	Fishery Law enforcement	Level of enforcement	in place
		Frequency of regular patrol	Number per week or month
		Number of violation prosecution	Decreasing
Capacity Building	Best Practice	Adoption of best practice in place	adoption
	Maritime policy and regulation/ International policy	Number of training/workshops	Number
Funding (Infrastructure, Enforcement, etc.)	Sustainability	Long term commitment of Government on finance	In placed
	Source of funding (Incentive, soft loan, donation/ CSR)	Number of donors	maintain/ increase
		Type of funds	Maintain or increase
	Incentive	Type and number of incentives	Number
		Number of activities	Number
		Number of best practices	Number

Table 4: Specified criteria and Indicators of the **Cross-cutting (Climate Change) Dimensions** for fisheries refugia approach

SUB-DIMENSIONS	CRITERIA	INDICATORS	UNITS/REF
On Fish Stock	Impact to Fish Stock	Availability/levels of knowledge abundance, distribution, genetic diversity, recruitment	**App.22** Refers to App01-08
		Update information impact to fish stock	Monitoring
Impact to Habitat	Coral bleaching	Area	hectare or Km^2
		Incident/ frequency	**App.23**
		Recovery Rate	%
	Destruction of mangrove	Area coverage	hectare or Km^2
		Recovery Rate	%
	Destruction of sea grass	Area coverage	hectare or Km^2
		Recovery Rate	%
Impact to Environment	Sea level rise	Saline intrusion (if appropriate)	**App.24**
		Mean sea level annual (if appropriate)	**App.25**
		Coastal Erosion (Area)	hectare or Km^2

	Physical/chemical parameters	Level of physical and chemical parameters (T, Salinity, PH, DO)	**App.26**
	Precipitation (rainfall)	Level of Precipitation (if appropriate)	**App.27**
	Ocean acidification	PH level	ppt.

App.01	**Biomass** Biomass (B) – Weight of an individual or a group of individuals contemporaneous of a stock. Abundance and biomass estimates are metrics usually taken for phytoplankton assays. Biomass is a proxy measure today in phytoplankton assays, while relative abundance is broadly used in diatoms investigations and application of ecological indexes.
App.02	**Maximun Sustainable Yield** (https://www.fao.org/3/y3427e/y3427e07.htm#bm07.3.1) In the 1960s and 1970s, maximum sustainable yield (MSY) was seen as the ideal target to aim for in managing fisheries, and managers attempted to obtain MSY through striving to set the MSY as a target catch level or to determine the fishing mortality rate that would generate MSY (FMSY). The maximum sustainable yield concept is based on a model, referred to as a surplus production or biomass dynamic model (**Figure 5**), which assumes that the annual net growth in abundance and biomass of a stock increases as the biomass of the stock increases, until a certain biomass is reached at which this net growth, or surplus production, reaches a maximum (the MSY). This biomass is referred to as BMSY, and the fishing mortality rate which will achieve MSY is similarly referred to as FMSY. As the biomass increases above BMSY, density dependent factors such as competition for food and cannibalism on smaller individuals start to reduce the net population growth which therefore decreases until at some point, the average carrying capacity of the stock, net population growth reaches zero. In reality, an unexploited stock will tend fluctuate about this biomass because of environmental variability.  Figure 5: Schaefer model of surplus production (biomass dynamic) as a function of stock size showing the major reference points. Other forms of surplus production model can have BMSY at a higher or lower stock size than the 50% of B0 of the Schaefer model. MSY = maximum sustainable yield; BMSY = the biomass at which MSY occurs; and B0 = the average unexploited biomass of the stock (the average 'carrying capacity').

	MSY was such a well-established target for managing fisheries that it is included in the 1982 United Nations Convention on the Law of the Sea (UNCLOS), where it is stated that coastal management agencies should "... maintain or restore populations of harvested species at levels which can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors". This requirement of the LOS is equivalent to specifying a limit reference point of BMSY. This is not the same as setting MSY as a target reference point for catch, however, and using MSY as a target reference point has been found to be dangerous. This is because it is impossible to estimate MSY precisely for any stock. If MSY is over-estimated, then a fishery will be allowed to take more than the maximum production of the stock which will cause a reduction in the biomass every year. In a new fishery this could drive the biomass down to the level at which MSY is produced (BMSY) but if continued after that will drive the biomass down further, where annual production gets smaller and smaller, making the situation even worse. Even if average MSY could be precisely determined, the productivity of a stock varies from year to year under the influence of environmental variability. Therefore, if the stock is at BMSY, in some years production may still be less than MSY and, if MSY is taken as the catch, the biomass will be driven below BMSY, possibly driving the stock into a downward spiral. Therefore, MSY is no longer seen as a target reference point for fisheries managers to strive for, although it can still be used as a limit reference point i.e. as an upper limit to the annual catch, which should be avoided.
App.03	**Maximum Economic Yield (MEY)** In fisheries terms, maximum sustainable yield (MSY) is the largest average catch that can be captured from a stock under existing environmental conditions. Relating to MSY, the maximum economic yield (MEY) is the level of catch that provides the maximum net economic benefits or profits to society. Fundamental theory in the science of fisheries economics was presented by a Canadian economist (Gordon, 1954). Later, Schaefer used these ideas to develop a mathematical model in an attempt to establish a relationship between biological growth and fishing activities. This model is known as Gordon-Schaefer model (GSM) and is the basic model of bioeconomic. The maximum capacity of the environment to support the highest fishery stock biomass (B) is referred to as carrying capacity (K). At K, the growth rate of the fishery stock virtually becomes zero. **Figure 6** graphically represents total revenue of the fishery with a constant price. In this figure, parabola corresponds to either equilibrium amount of fishing effort or the equilibrium of B. The straight line represents total cash flow when the operating and fixed costs are constant. The slope of this line is equal to the cash flow per fishing effort. Economic rent is represented by the difference of the cost line and revenue curve. This economic rent is supposed to be derived from the fishery stock. The highest difference between the cost of economic rent is the maximum. The point at which revenue curve is intersected by the coastline is known as the open access equilibrium (OAE).

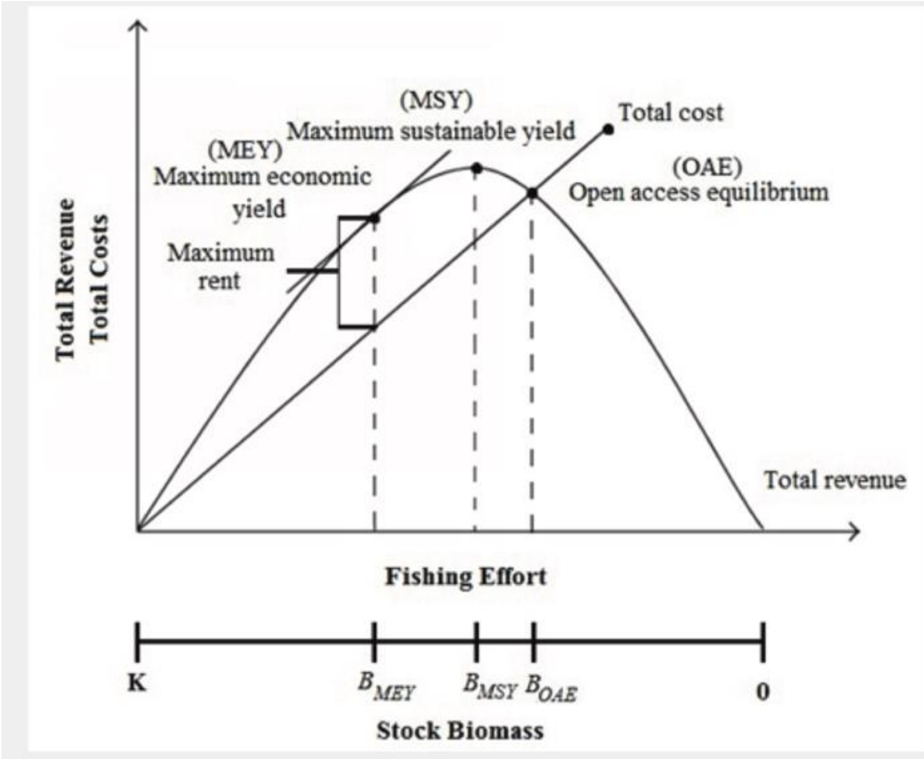
<table>
<tr><td></td><td>


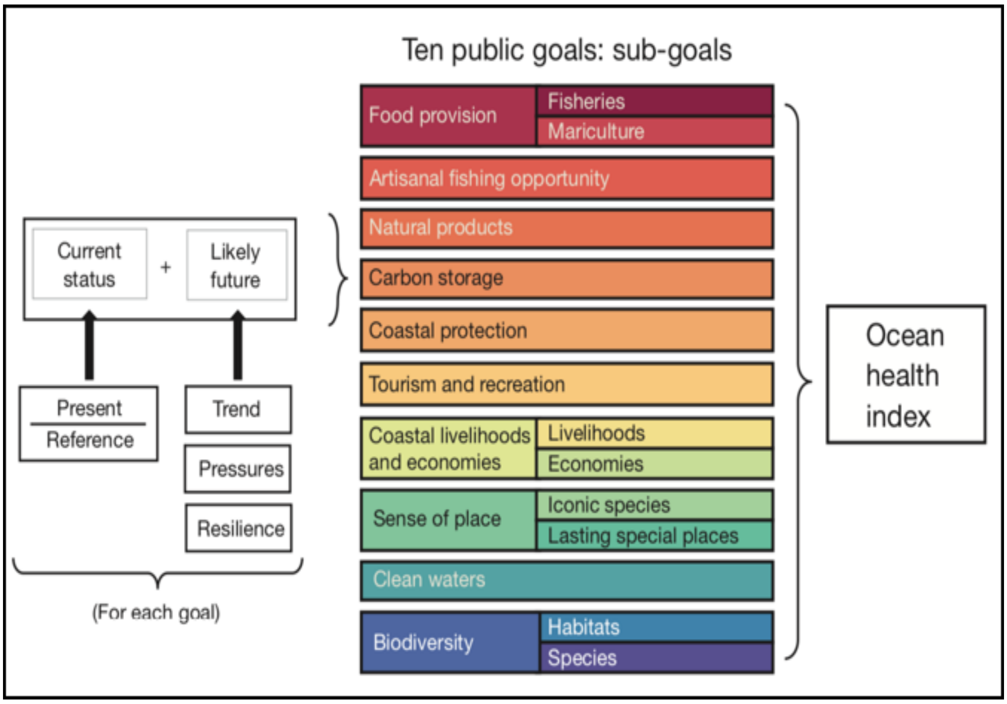
Figure 6: Total revenue of the fishery with constant price
</td></tr>
<tr><td>App. 04</td><td>
Length at first capture (Lc)

The size of a fish at first capture is the size after the fish has bred for the first time. This size will vary in case of both males & females. This size will not be the same for all the varieties of fish. Hence a fishery biologist will be able to say the size of a variety of fish soon after it has bred. In case fish before first capture is not allowed to breed, it is most likely, that the stocks will dwindle in course of time. They will decline sooner if the life span of fish is small, will take more time if life span is longer, other conditions being the same.
</td></tr>
<tr><td>App.05</td><td>
Length at first Mature (Lm)

The size of fish at first maturity (Lm50) is the length at which 50% of the fish have reached maturity. In the present study it was noticed that the 50% of observed sexual maturity of male and female fishes were in the matured stage. The large and whitish testis and yellowish orange ovaries are defined as matured

For estimating Lm, different researchers use different methodologies. Some uses the lowest recorded mature fish as Lm. Some researchers estimated it by eye observation of visible egg. Some estimates from the first peak of GSI. Some uses cumulative percentage of all samples of fully matured egg (Stage v and above) to estimate Lm. But is there any method to calculate Lm based on histological stages (i-vii) and maturity stages i.e., cumulative percentage of samples over certain maturity stages (stages i-vii/viii)
</td></tr>
<tr><td>App.06</td><td>
Spawning Potential Ratio (SPR)

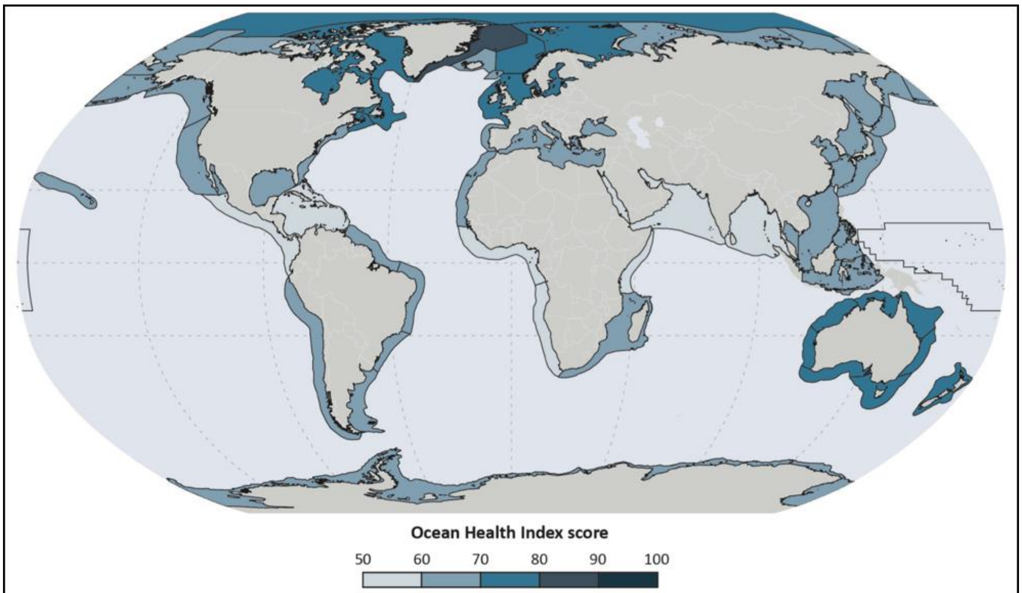
The spawning potential ratio (SPR) of a stock is defined as the proportion of the unfished reproductive potential left at any given level of fishing pressure (Goodyear, 1993; Walters and Martell, 2004) and is commonly used to set target and limit reference points for fisheries. The spawning potential ratio (SPR)—an index developed by marine fisheries scientists to identify and prevent recruitment overfishing—is simply a ratio of the average
</td></tr>
</table>

	lifetime production of mature eggs per recruit in a fished population to what it would have been if the population had never been fished.
App.07	**Exploitation rate** Exploitation rate, applied on a fish stock, is the proportion of the numbers or biomass removed by fishing. If the biomass is 1000 tons and the harvest during a year is 200 tons, the annual exploitation rate is 20%.
App.08	**Gonadosomatic index (GSI)** The gonadosomatic index, abbreviated as GSI, is the calculation of the gonad mass as a proportion of the total body mass. It is represented by the formula: GSI = [gonad weight / total tissue weight] × 100
App.09	**Ocean Health Index** One of the greatest challenges for resource management, including for LMEs, is to understand the condition of human and natural systems within a region and make informed decisions about the best way to improve that condition. Too often, monitoring, assessments, indicator choice, and decisions are made within a single sector or aimed at a single objective, without adequate consideration of the broader implications of proposed actions. Ecosystem-based management and marine spatial planning aim to overcome these management barriers, but there are relatively few tools to inform and support these comprehensive management approaches. Without a tool to measure overall ecosystem health and track progress towards improving it, one cannot effectively manage towards that objective. Together, the five LME modules capture many of the indicators of a healthy ocean ecosystem, but incompletely and without a transparent and quantitative means to combine the various measures. The Ocean Health Index (OHI) was developed in part to address this need. Using a common framework, the OHI measures progress towards achievement of ten widely agreed public goals for healthy oceans, including food provision, carbon storage, coastal livelihoods and economies, and biodiversity (Figure 7). Progress towards each goal is assessed against the optimal and sustainable level that can be achieved (Figure 8). 

Definitions of the goals and sub-goals of the Ocean Health Index

Goal	Sub-goal	Definition
Food provision (FP)	Mariculture (MAR)	Production of sustainably cultured seafood
	Fisheries (FIS)	Harvest of sustainably caught wild seafood
Artisanal fishing opportunity (AO)		Opportunity to engage in artisanal-scale fishing for subsistence and/or recreation
Natural products (NP)		Sustainable harvest of natural products, such as shells, algae, and fish oil used for reasons other than food provision
Coastal protection (CP)		Conservation status of natural habitats affording protection of the coast from inundation and erosion
Carbon storage (CS)		Conservation status of natural habitats affording long-lasting carbon storage
Coastal livelihoods and economies (LE)	Coastal livelihoods (LIV)	Jobs and wages from marine-related sectors
	Coastal economies (ECO)	Revenues from marine-related sectors
Tourism and recreation (TR)		Opportunity to enjoy coastal areas for recreation and tourism
Sense of place (SP)	Lasting special places (LSP)	Cultural, spiritual, or aesthetic connection to the environment afforded by coastal and marine places of significance
	Iconic species (ICO)	Cultural, spiritual, or aesthetic connection to the environment afforded by iconic species
Clean waters (CW)		Clean waters that are free from nutrient and chemical pollution, marine debris, and pathogens
Biodiversity (BD)	Species (SPP)	The existence value of biodiversity measured through the conservation status of marine-associated species
	Habitats (HAB)	The existence value of biodiversity measured through the conservation status of habitats

Figure 8: Ocean Health Index score by LME

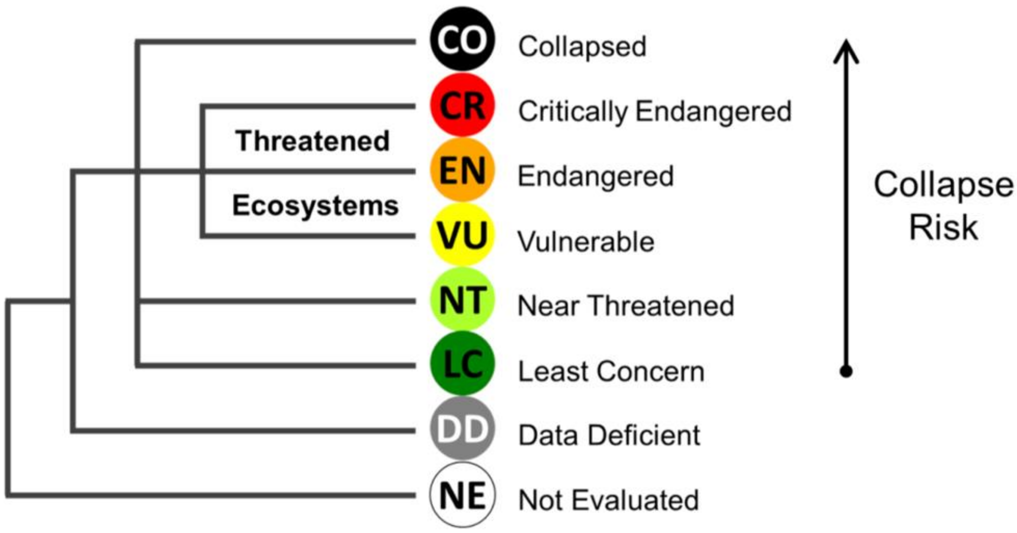


App.10 **Target habitat density (IUCN reference)**

The primary goal of the IUCN Red List of Ecosystems (RLE) is to support conservation in resource use and management decisions by identifying ecosystems most at risk of biodiversity loss (Keith et al., 2013). By assessing relative risks of biodiversity loss at the ecosystem level, the RLE accounts for broad scale ecological processes and important dependencies and interactions among species (Keith et al., 2015).

The IUCN Red List of Ecosystems includes eight categories: Collapsed (CO), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE; Figure 9). The first six categories (CO, CR, EN, VU, NT and LC) are ordered in decreasing risk of collapse. The categories Data Deficient and Not Evaluated do not indicate a level of risk.

The categories Critically Endangered, Endangered and Vulnerable indicate threatened ecosystems and are defined by quantitative and qualitative criteria described in Section 5 and Appendix 2. These categories are nested, so that an ecosystem type meeting a criterion

	for Critically Endangered will also meet the criteria for Endangered and Vulnerable. The three threatened ecosystem categories are complemented by several qualitative categories that accommodate: (i) ecosystem types that almost meet the quantitative criteria for Vulnerable (Near Threatened); (ii) ecosystems that unambiguously meet none of the quantitative criteria (Least Concern); (iii) ecosystems for which too few data exist to apply any criterion (Data Deficient); (iv) ecosystems that have not yet been assessed (Not Evaluated). Following the precautionary principle (Precautionary Principal Project, 2005), the overall status of an ecosystem type is the highest risk category obtained through any criterion.  Figure 9: Structure of IUCN Red List of Ecosystem categories
App.11	**Standard Water Quality Parameters** Parameters that are frequently sampled or monitored for water quality include temperature, dissolved oxygen, pH, conductivity, ORP, and turbidity. However, water monitoring may also include measuring total algae, ISEs (ammonia, nitrate, chloride), or laboratory parameters such as BOD, titration, or TOC.
App.12	**Phytoplankton Composition and Abundance** The phytoplankton is one of the most important communities in aquatic ecosystem, constituting the first step of diverse trophic chain, and being one of the main primary producers in the marine, coastal, and continental water bodies. It provides food for primary consumers from zooplankton, benthos, and nekton communities (Harris 1986; Hernández-Becerril 1993). Accordingly, to Metting (1996) microalgae are primarily responsible for the 40–50% of total global photosynthetic primary production. Another important function of phytoplankton in natural or aquaculture ecosystems is the production of oxygen. It has been demonstrated that a great proportion of oxygen in the atmosphere and the water column come from phytoplankton photosynthesis (Balkanski *et al*. 1999). The composition and abundance of phytoplankton vary widely in the diverse aquatic ecosystems, exhibiting sometimes a pronounced seasonal succession, influenced by diverse factors such as temperature and salinity (Muylaert *et al.* 2000), as well as changes in the concentration and proportion of nutrients, resulting from movements of water masses, upwellings, and continental drains
App.13	**Phosphate, Nitrate Concentration (Nutrient loading)**

	Nitrogen (N) and phosphorus (P) are key nutritional elements for many important life processes such as protein and DNA synthesis, primary production, cellular growth and reproduction. Both have a natural global cycle that includes conversion between different inorganic and organic forms, solid and dissolved (and gaseous for nitrogen) phases that maintained their pre-industrial concentrations within certain natural bounds. During the preindustrial era, the concentrations and fluxes of N and P in rivers were generally small, much less than present day levels, and were mainly sourced from erosion and the leakage of dissolved N and P in their organic/inorganic forms. Today anthropogenic production of N and P to support fertilization and industrial releases has dramatically increased the N and P presence in water bodies. However, in excessive quantities, they may represent a significant source of aquatic pollution. Eutrophication has become a widespread issue rising from a chemical nutrient imbalance and is largely attributed to anthropogenic activities in both inland and coastal waters.
App.14	**Fish Consumption Per Capita Per Year** Per capita consumption is the average use of a product, service or other item per person. You can calculate the per capita consumption of a particular food, for example, if you are interested in investing in a commodity. You can calculate per capita consumption as it relates to a country's economic activity, such as Gross Domestic Product. You can make a quick calculation to help you make comparisons by year to see if something you're researching is trending upward or downward.
App.15	**Poverty Index/Income Poverty** Literature has been built on the Forster-Greer-Thorbecke (FGT) (1) poverty index to estimate **income poverty** (2) (Akongyuure et al., 2017). However, the income poverty has several drawbacks that include using income as the lone indicator of measuring the wellbeing of an individual and hence limited since it does not reflect and incorporate the key dimensions of poverty associated with the quality of life. Also, the income poverty approach does not guarantee that households with income at or above the poverty line would use their incomes to purchase the minimum basic needs. This implies that households may be non-poor in terms of income but deprived of basic needs (Kabubo-Mariara et al., 2011). This infers that income poverty is an indirect approach to assess the ability of the household to satisfy basic needs. Therefore, the study focused its analysis on the multidimensional measurement of poverty (3). 1) Forster-Greer-Thorbecke (FGT) poverty index is a poverty measure in a population defined as; $y_i = z - v_i z$ where, v_i = Per capita income of household i, z = Poverty line; thus, households with income above the poverty line are assigned zero Y_i = Income poverty gap that is a continuous variable ranging between zero and one. 2) Income poverty refers to a failure to satisfy basic needs using per capita income as a threshold. 3) Multidimensional poverty offers an added advantage compared to income poverty since it enables the researcher to directly assess the types of basic needs a household can actually satisfy. Also, the approach allows for decomposability and offers freedom in assigning different weights to different indicators (Kabubo-Mariara et al., 2011). In this sense, multidimensional poverty indicators for quantitative impact analysis and weighted procedures for the multidimensional poverty index (MPI) were applied. The approach was preferred to factor and cluster

analyses because it provides absolute poverty levels and allows for poverty comparison across different settings (Ogutu and Qaim, 2018).

Dimension and indicator	Description and deprivation cutoff
Education	
School achievement	Deprived if the household head and spouses have not completed the primary level of education
School attendance	Deprived if the household has school-aged children not going to school
Standard of living	
Electricity	Deprived if the household has no electricity
Drinking water	Deprived if the household does not have access to safe drinking water or they have to walk over 30 min to get safe drinking water
Sanitation	Deprived if the household has no descent pit latrine
Flooring	Deprived if the household house is earth
Assets	
Phone	Deprived if the household does not own a mobile phone
Radio and/or television	Deprived if the household does not own at least radio
Vehicle	Deprived if the household does not own at least a bicycle
Health	
Nutrition 1	Deprived if the household reports a household dietary diversity score of 6 and below out of the possible 12 food groups
Nutrition 2	Deprived if the household relies on relief food or any case of malnutrition in the past 2 years
Access	Deprived if the household has difficulty in meeting basic public hospital bills
Source: Adapted from Ayuya et al. (2015).	

App.16 **Catch Per Unit Effort (CPUE)**

Catch-per-unit effort (CPUE) methods can be used to estimate absolute abundance of closed populations in the presence of successive removals. This estimation is possible because of the proposed relationship between harvest effort and the probability of capture, as well as the observed decline in catch with successive removal events. A minimum of two samples is necessary for abundance estimation and a minimum of three samples for tests of goodness-of-fit. With only a single sample catch of size r, the catch represents, under ideal circumstances, an index to abundance where its expected value is

$$E(ri). \ =. \ Ni \times pi$$

where

ri = number of fish caught in the i^{th} population;

Ni = fish abundance in the i^{th} population;

Pi = probability of capture exerted on the i^{th} population

Seasonal and annual CPUE estimates are often used to index abundance and to track the depletion of the fished stock as fishing progresses though the season (see 'Modelling the Depletion Process' section). Limitations of CPUE as an index of abundance, however, are well-understood, and they tend to be particularly severe in the case of sedentary organisms.

The assumption is that the number of fish caught per unit of effort expended (often time) is proportional to stock size. However, experience from commercial fisheries shows that CPUE

	can remain high in the face of a rapidly declining stock or decline even if the stock is relatively stable (Hilborn and Walters, 1992).
App.17	**Cost Effectiveness Analysis** Cost-effectiveness analysis (CEA) is a form of economic analysis that compares the relative costs and outcomes (effects) of different courses of action. Cost-effectiveness analysis is distinct from cost–benefit analysis, which assigns a monetary value to the measure of effect. The concept of cost-effectiveness is applied to the planning and management of many types of organized activity. The major steps in a cost-benefit analysis • Step 1: Specify the set of options. • Step 2: Decide whose costs and benefits count. • Step 3: Identify the impacts and select measurement indicators. • Step 4: Predict the impacts over the life of the proposed regulation. • Step 5: Monetise (place dollar values on) impacts.
App.18	**Reduce of Fuel Consumption** Compared to a century ago, the world's fishing fleets are larger and more powerful, are traveling further, and are producing higher quality products. These developments come largely at a cost of high-fossil fuel energy inputs. Rising energy prices, climate change, and consumer demand for 'green' products have placed energy use and emissions among the sustainability criteria of food production systems. Management decisions, technological improvements and behavioral changes can further reduce fuel consumption in the short term, although the most effective improvement to fisheries energy performance will come as a result of rebuilding stocks where they are depressed and reducing over-capacity.
App.19	**Reduce Bycatch** Fishers, fishing gear designers and manufacturers, researchers and government and non-government organizations needs to work together to the development of solutions for reducing bycatch. Fishers (commercial, recreational and Indigenous) bring an understanding of how to efficiently catch their target species, how their gear works and what is practical and safe at sea. Fishers in high latitudes often design fishing gear and practices to reduce bycatch as it is in their interests to avoid catching non-target species. They also bring their observations and records of when and where they have caught bycatch. Fishing gear designers and manufacturers contribute by using their knowledge of how their gear works and the different materials that can be used. They can modify gear or design innovations to ensure the gear still catches the target species but not the bycatch. For example, changes to hook shape or net design can reduce bycatch. A good example of gear innovations is the incorporation of Turtle Excluder Devices (TEDs) into net designs used in tropical prawn trawl fisheries. TEDs allow prawns to enter a net yet prevent large marine animals like turtles from being captured. The device has proven to be highly successful in many fisheries around the world.
App.20	**Input Controls or Fishing Effort Management** As defined above, input controls are restrictions put on the intensity of use of gear that fishers use to catch fish. Most commonly these refer to restrictions on the number and size of fishing vessels (fishing capacity controls), the amount of time fishing vessels are allowed

	to fish (vessel usage controls) or the product of capacity and usage (fishing effort controls). Often fishing effort is a useful measure of the ability of a fleet to catch a given proportion of the fish stock each year. When fishing effort increases, all else being equal, we would expect the proportion of fish caught to increase. For some fisheries, vessels may deploy a variable amount of fishing gear. In these cases the definition of fishing effort would also need to contain a factor relating to gear usage per vessel. In principle, input controls might also refer to limits placed upon other vital supplies of fishing such as the amount of fuel use allowed (energy conservation is desirable, see Paragraphs 8.6.1 and 8.6.2 in the Code of Conduct) but the commonest form of input controls are those put on the various components of fishing effort. In simpler less mechanized fisheries input controls might relate to the number of fishing gears deployed (e.g. the number of static fish traps) or to the number of individual fishers allowed to fish. In summary, the Input Control refers to number of gears, mesh size, length of fishing gear, Licensing control, fishing capacity (e.g. Gross tonnage, horsepower, etc.).
App.21	**Output Controls or Catch Management** By contrast, output controls are direct limits on the amounts of fish coming out of a fishery (fish is used here to include shellfish and other harvested living aquatic animals). Obvious forms of output control are limits placed upon the tonnage of fish or the number of fish that may be caught from a fishery in a period of time (e.g. total allowable catches (TAC); in reality, usually total allowable landings). Another form of output control is the bag limits (restrictions of the number of fish that may be landed in a day) used in many recreational fisheries. Limiting bycatch might also be seen as an output control. It is worth immediately noting that to limit fishing intensity it is necessary (unless, as is not usually the case, fish can be released alive) to limit the catch (the amount taken from the sea) rather than the landing (which may well contain only a selection of the catch). The unlanded part of the catch (the discards) may be a substantial proportion of the total catch (Alverson et al, 1994) and may undermine the intent of catch management.
App.22	**Climate Change Impact** Climate change has been recognized as the foremost environmental problem of the twentyfirst century and has been a subject of considerable debate and controversy. It is predicted to lead to adverse, irreversible impacts on the earth and the ecosystem as a whole. Although it is difficult to connect specific weather events to climate change, increases in global temperature has been predicted to cause broader changes, including glacial retreat, arctic shrinkage and worldwide sea level rise. Climate change has been implicated in mass mortalities of several aquatic species including plants, fish, corals and mammals. Climate change, in particular, rising temperatures, can have both direct and indirect effects on global fish production. With increased global temperature, the spatial distribution of fish stocks might change due to the migration of fishes from one region to another in search of suitable conditions. Climate change will have major consequences for population dynamics of marine biota via changes in transport processes that influence dispersals and recruitment (Barange and Perry, 2009). These impacts will differ in magnitude and direction for populations within individual marine species whose geographical ranges span large gradients in latitude and temperature, as experimented by Mantzouni and Mackenzie (2010) in cod recruitment throughout the north Atlantic. The effects of increasing temperature on marine and freshwater ecosystems are already evident, with rapid pole ward shifts in distributions of fish and plankton in regions such as North East Atlantic, where temperature change has been rapid (Brander, 2007). Climate change has been implicated in mass mortalities of many aquatic species, including plants, fish, corals, and mammals.

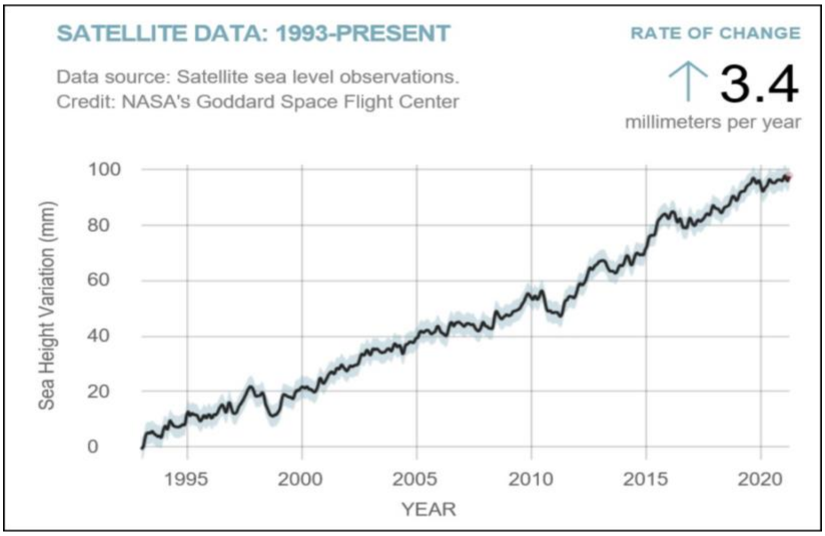
App.23	**Coral bleaching** Coral bleaching is the process when corals become white due to various stressors, such as changes in temperature, light, or nutrients. Bleaching occurs when coral polyps expel the algae that live inside their tissue, causing the coral to turn white. The leading cause of coral bleaching is climate change. A warming planet means a warming ocean, and a change in water temperature—as little as 2 degrees Fahrenheit—can cause coral to drive out algae. Coral may bleach for other reasons, like extremely low tides, pollution, or too much sunlight. (www.worldwildlife.org)
App.24	**Saline Intrusion** Saltwater intrusion is the movement of saline water into freshwater aquifers, which can lead to groundwater quality degradation, including drinking water sources, and other consequences. Saltwater intrusion can naturally occur in coastal aquifers, owing to the hydraulic connection between groundwater and seawater. The impact to inland not to the coastal area where refugia set.
App.25	**Mean Sea Level Annual, Rising sea levels** The systematic warming of the planet is directly causing global mean sea level to rise in two primary ways: (1) mountain glaciers and polar ice sheets are increasingly melting and adding water to the ocean, and (2) the warming of the water in the oceans leads to an expansion and thus increased volume. Global mean sea level has risen approximately 210–240 millimeters (mm) since 1880, with about a third coming in just the last two and a half decades. Currently, the annual rise is approximately 3mm per year. Regional variations exist due to natural variability in regional winds and ocean currents, which can occur over periods of days to months or even decades. But locally other factors can also play an important role, such as uplift (e.g. continued rebound from Ice Age glacier weight) or subsidence of the ground, changes in water tables due to water extraction or other water management, and even due to the effects from local erosion. Rising sea levels (Figure 10) create not only stress on the physical coastline, but also on coastal ecosystems. Saltwater intrusions can be contaminating freshwater aquifers, many of which sustain municipal and agricultural water supplies and natural ecosystems. As global temperatures continue to warm, sea level will keep rising for a long time because there is a substantial lag to reaching an equilibrium. The magnitude of the rise will depend strongly on the rate of future carbon dioxide emissions and future global warming, and the speed might increasingly depend on the rate of glacier and ice sheet melting. 

	Figure 10: https://en.wikipedia.org/wiki/Sea_level_rise#/media/File:NASA-Satellite-sea-level-rise-observations.jpg
App.26	**Level of physical and chemical parameters (T, Salinity, PH, DO)** Refers to SEAFDEC Collaborative Research Program in the South China Sea and Gulf of Thailand from 1995-2000 http://map.seafdec.org/mapgallery/
App.29	**Level of Precipitation** **Light rain** — when the precipitation rate is < 2.5 mm (0.098 in) per hour. **Moderate rain** — when the precipitation rate is between 2.5 mm (0.098 in) – 7.6 mm (0.30 in) or 10 mm (0.39 in) per hour. **Heavy rain** — when the precipitation rate is > 7.6 mm (0.30 in) per hour, or between 10 mm (0.39 in) and 50 mm (2.0 in) per hour.

CHAPTER 4: GLOSSARY

As a basis for common understanding on the key terminologies used in this Guidelines, explanation on the following terminologies are provided.

Anthropogenic: Anthropogenic referring to environmental change caused or influenced by people, either directly or indirectly. The anthropogenic activities include mining, release of industrial waste, smelting of As ore, incineration of fossil fuel, particularly coal, utilization of As-loaded water for irrigation, and As-based pesticides, herbicides, and fertilizers (Karimi et al., 2009).

Biodiversity: The variable among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Diversity indices are measures of richness (the number of species in a system; and to some extent, evenness (variances of species' local abundance). They are therefore indifferent to species substitutions which may, however, reflect ecosystem stresses (such as those due to high fishing intensity).

Catch quotas: Systems that use individual transferable quotas (ITQ), also called individual fishing quota limit the total catch and allocate shares of that quota among the fishers who work that fishery. Fishers can buy/sell/trade shares as they choose. A large-scale study in 2008 provided strong evidence that ITQ's can help to prevent fishery collapse and even restore fisheries that appear to be in decline. Other studies have shown negative socio-economic consequences of ITQs, especially on small-scale fisheries. These consequences include concentration of quota in those hands of few fishers; increased number of inactive fishers leasing their quotas to others (a phenomenon known as armchair fishermen); and detrimental effects on coastal communities.

Eutrophication: Eutrophication is the process by which an entire body of water, or parts of it, becomes progressively enriched with minerals and nutrients. It has also been defined as "nutrient-induced increase in phytoplankton productivity. When the eutrophication phenomenon becomes particularly intense, undesirable effects and environmental imbalances are generated. The two most acute phenomena of eutrophication are hypoxia in the deep part of the lake (or lack of oxygen) and algal blooms that produce harmful toxins, processes that can destroy aquatic life in the affected areas (www.unep.or.jp)

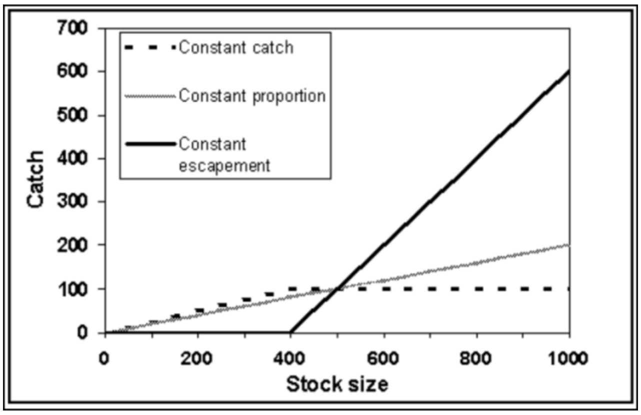
Fisheries management: The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and accomplishment of other fisheries objectives.

Fishing Effort: Amount of fishing vessels and gears of a specific type (or numbers of fishing unit or total engine capacity of fishing unit) used in the fishing ground over a given unit of time.

Harvest Strategy (https://www.fao.org/3/y3427e/y3427e07.htm#bm07.3.1)

Input and output controls are usually set on the basis of one of three basic harvesting strategies (not to be confused with management strategies: a harvesting strategy is one component of the management strategy). The three basic harvesting strategies are: constant catch; constant proportion or constant harvest rate (equivalent to constant effort if catchability of the resource remains the same); and constant escapement (Figure 1). A constant catch strategy will, by definition, result in no change in catch from year to year. However, for the manager to implement a constant catch strategy, that catch must be set low enough to apply in bad years as well as in good years, without damaging the future productivity of the stock, and must therefore be set at a relatively low level. Therefore the fisher pays a price for the absence of inter-annual variability in catch in a constant catch strategy by foregoing potential catch in good years. In a constant proportion strategy, the effort remains constant and therefore there will be changes in catch from year to year as the resource varies over good, bad and intermediate years. This variability results in some uncertainty about future catches for the fisher compared to the constant catch strategy. It also has benefits for the fisher, though, as it means the catches will be higher in good years, in contrast to the constant catch strategy, generally leading to a higher annual average catch. A constant escapement strategy (or constant stock size strategy) would aim to ensure that a constant biomass, sufficient to maintain recruitment, was left at the end of every fishing season. This type of strategy tends to achieve the highest annual average catches of the three categories but with the highest variability, in many cases including zero catches in some years.

The decision on which type of harvesting strategy to pursue should be made from a knowledge of the requirements of the fishery and with consultation with the interest groups on the tradeoffs they would like to make between maximizing catch and minimizing variability. The much more difficult question is, given one of the strategies, how does the manager decide on the actual catch, effort or escapement which should be set under the strategy. This is discussed in later sections of the chapter. It should also be noted that these harvesting strategies could all be pursued using output control (setting a TAC), input control (setting the effort that can be expended in a year), or even the use of closed seasons (which can be a form of output control.



Simple examples of the three classes of harvesting strategy and their relationship to stock size: constant catch (with provision for a linearly decreasing catch when the stock size falls below 400); constant proportion; and constant escapement (after Hilborn and Walters, 1992).

Harvest strategies are pre-agreed frameworks for making fisheries management decisions, such as setting quotas. They are akin to agreeing to the rules before playing the game and shift the perspective from short-term reactive decision-making to longer-term objectives. Harvest strategies use data and information to track the performance of the fishery over time. Such sources of information are known as indicators. These include things like biomass, catch rates, protected species interactions etc.

Maximum sustainable yield (MSY) – Highest yield of fish that can be harvested on a sustainable basis from a fish stock by a given number of fishing efforts within a period under existing environmental conditions.

Precautionary principle - A Fishery Manager's Guidebook issued in 2002 by the FAO advises that a set of working principles should be applied to "highlight the underlying key issues" of fisheries management." There are 8 principles that should be considered as a whole in order to best manage a fishery. The first principle focuses on the finite nature of fish stocks and how potential yields must be estimated based on the biological constraints of the population.

In a paper published in 2007, Shertzer and Prager suggested that there can be significant benefits to stock biomass and fishery yield if management is stricter and more prompt.[19] This is supported by recent work on the management of North Sea fisheries in accordance with ranges of acceptable fishing, where fishing at the top of the "acceptable" ranges is many times more risky than fishing near the bottom, but delivers only 20% more yield.

Stakeholders - Individuals or groups of individuals who are involved in utilization of fishery resources and have interests in the fisheries. In fishery statistics context, stakeholders refer to individuals or groups of individuals who are involved in the production and/or usage of fishery statistics for certain purposes.

ACKNOWLEADGEMENTS

REFERENCES

1) Hornborg S, Belgrano A, Bartolino V, Valentinsson D, Ziegler F. (2013): Trophic indicators in fisheries: a call for re-evaluation. Biol Lett 9: 20121050. http://dx.doi.org/10.1098/rsbl.2012.1050

2) Julie De Wit, Jim Lafere and Luc Hens (2004): Indicators for Sustainable Development and Environmental Health Indicators for Flanders (Northern Belgium). Human Ecology Special Issue No. 12: 131-141

3) FAO (1999): Indicators for sustainable development of marine capture fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 8. Rome, FAO. 1999. 68p.

4) Elkington, J. (1997): Cannibals with Forks: The Triple Bottom Line of 21st Century Business. Capstone, Oxford.

5) United Nations (1993): Agenda 21: Earth's Action Plan. New York, Oceania Publications.

6) IUCN (1980): World Conservation Strategy. Living Resource Conservation for Sustainable Development. Gland, Switzerland, International Union for the Conservation of Nature & United Nation Environment Program, FAO/UNESCO: 44p.

7) Paterson, C.J., *et al*. (2012): Fisheries refugia: A novel approach to integrating fisheries and habitat management in the context of small-scale fishing pressure, Ocean & Coastal Management, http://dx.doi.org/10.1016/j.ocecoaman.2012.12.001

8) SEAFDEC (2003): Regional Guidelines for Responsible Fisheries In Southeast Asia: Fisheries Management, Southeast Asian Fisheries Development Center. Bangkok, Thailand. 69p.

9) Rapport D, Friend A (1979): Towards a comprehensive framework for environmental statistics: a stress-response approach. Statistics Canada Catalogue 11-510. Minister of Supply and Services Canada, Ottawa. 90 pp.

10) Delpeuch, C. and B. Hutniczak (2019): Encouraging policy change for sustainable and resilient fisheries, OECD Publishing, https://doi.org/10.1787/31f15060-en

11) FishStatJ (2016): Database and software for fishery statistical analysis. United Nations FAO. Accessed 28 June 2016. http://www.fao.org/fishery/statistics/software/fishstatj/en

12) SEAFDEC. (2019): SEAFDEC Gender Strategy—Mainstreaming gender in SEAFDEC and its programs. Southeast Asian Fisheries Development Center. Bangkok, Thailand.

13) GEF SEC (2018): Guidance to Advance Gender Equality in GEF Projects and Programs. Global Environment Facility. 33p.

14) Gordon HS (1954) The economic theory of a common-property resource: The fishery. J Pol Eco 62(2): 124-142.

15) Goodyear, C. P. (1993): Spawning stock biomass per recruit in fisheries management: foundation and current use. In Risk Evaluation and Biological Reference Points for Fisheries Management, 120, pp. 67–81. Ed. by S. J. Smith, J. J. Hunt, and D. Rivard. Canadian Special Publications of Fisheries Aquatic Sciences.

16) Walters, C. J., and Martell, S. J. D. (2004): Fisheries Ecology and Management. Princeton University Press, Princeton, USA.

17) Keith, D.A., Rodríguez, J.P., Rodríguez-Clark, K.M. *et al*.(2013): Scientific foundations for an IUCN Red List of Ecosystems. PLoS One, 8(5), e62111.

18) Keith, D.A. (2015): Assessing and managing risks to ecosystem biodiversity. Austral Ecol. 40, in press [doi:10.1111/aec.12249].

19) C.P. Harris (1986): Phytoplankton Ecology. Structure, Function, and Fluctuation Chapman and Hall, London.

20) D. Hernández-Becerril (1993): Fitoplancton marino en México. S. Salazar-Vallejo, N. González (Eds.), Biodiversidad marina y costera de México, CONOABIO & CIQRO, México (1993), pp. 39-53.

21) F.B. Metting Jr. (1996): Biodiversity and application of microalgae. J. Ind. Microbiol., 17 (1996), pp. 477-489

22) Y. Balkanski, P. Monfray, M. Battle, M. Heimann (1999): Ocean primary production derived from satellite data: an evaluation with atmospheric oxygen measurements. Global Biogeochem. Cycles, 13, pp. 257-271.

23) K. Muylaert, K. Sabbe, W. Vyverman (2000): Spatial and temporal dynamics of phytoplankton community in a freshwater tidal estuary (Schelde, Belgium) Estuar. Coast Shelf Sci., 50 (2000), pp. 673-687.

24) Akongyuure DN, Amisah S, Agyemang TK, et al. (2017): Tono reservoir fishery contribution to poverty reduction among fishers in Northern Ghana. Afr J Aquat Sci 42: 143–154.

25) Kabubo-Mariara J, Wambugu A, Musau S (2011): Multidimensional poverty in Kenya: Analysis of maternal and child wellbeing. PEP PMMA 12.

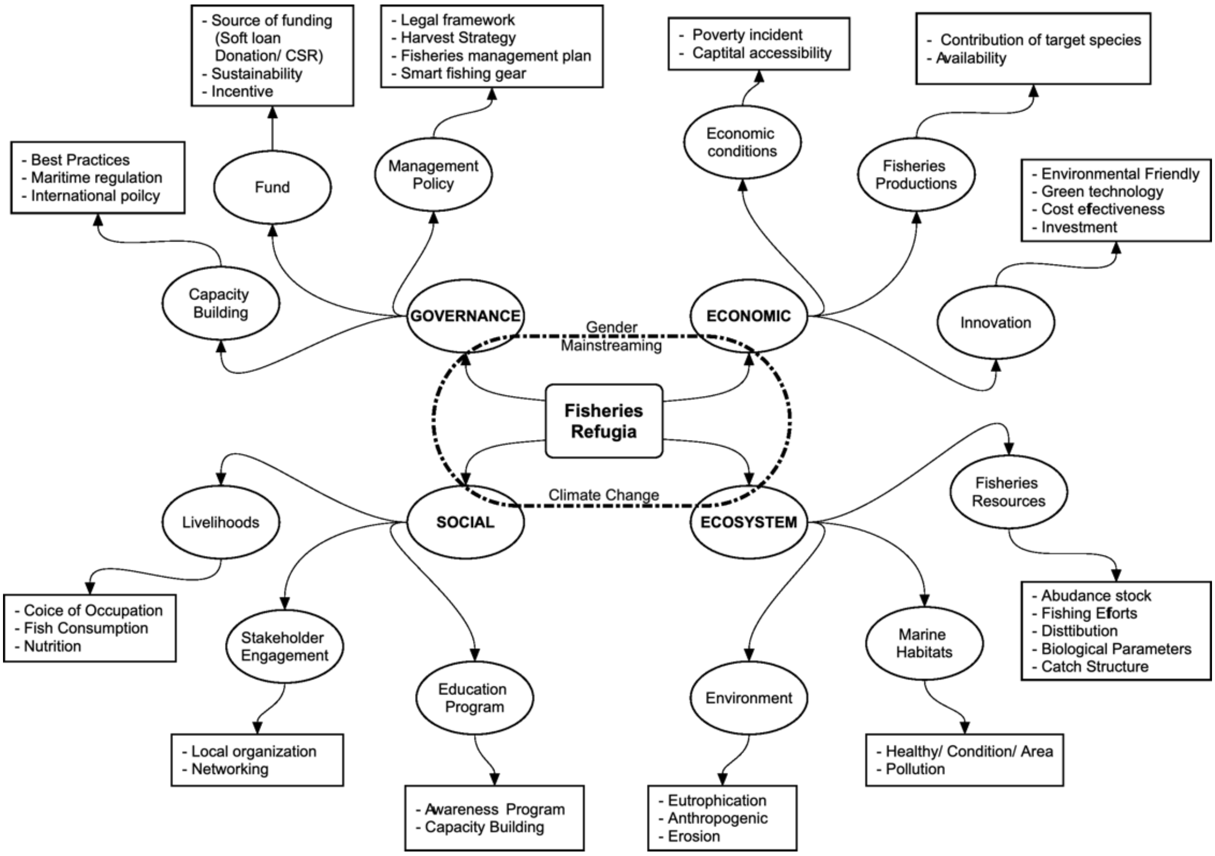
26) Ogutu SO, Qaim M (2018) Commercialization of the small farm sector and multidimensional poverty (No. 117). Global Food Discussion Papers.

27) Ray Hilborn, Carl J. Walters (1992): Quantitative Fisheries Stock Assessment. Springer, Boston, MA.

28) Alverson, D. L., Freeberg, M. H., Murawski, S. A., and Pope, J.G. (1994): A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper, 339. FAO, Rome. 233pp.

29) Barange, M., & Perry, R.I. (2009): Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture In: Climate change implications for fisheries and aquaculture overview of current scientific Knowledge, Cochrane, K., Young, C. De, Soto, D., & Bahri, T. (Eds). FAO Fisheries and Aquaculture Technical paper: No. 530, pp. 7-106, FAO, Rome

30) Mantzouni, I., & Mackenzie, B. R. (2010): Productivity responses of a widespread marine piscivore, Gadus morhua, to oceanic thermal extremes and trends. Proc Biol Sci. Feb 10. [Epub ahead of print].


Fisheries Refugia
Gender Mainstreaming
Climate Change
GOVERNANCE
ECONOMIC
SOCIAL
ECOSYSTEM
Capacity Building
Fund
Management Policy
- Best Practices
- Maritime regulation
- International poilcy
- Source of funding (Soft loan Donation/ CSR)
- Sustainability
- Incentive
- Legal framework
- Harvest Strategy
- Fisheries management plan
- Smart fishing gear
Economic conditions
Fisheries Productions
Innovation
- Poverty incident
- Captital accessibility
- Contribution of target species
- Availability
- Environmental Friendly
- Green technology
- Cost effectiveness
- Investment
Livelihoods
Stakeholder Engagement
Education Program
- Coice of Occupation
- Fish Consumption
- Nutrition
- Local organization
- Networking
- Awareness Program
- Capacity Building
Fisheries Resources
Marine Habitats
Environment
- Abudance stock
- Fishing Efforts
- Disttibution
- Biological Parameters
- Catch Structure
- Healthy/ Condition/ Area
- Pollution
- Eutrophication
- Anthropogenic
- Erosion