



AFRICAN UNION  
**INTERAFRICAN BUREAU  
FOR ANIMAL RESOURCES**



## **FISHERIES MANAGERS' TRAINING GUIDE:**

A TECHNICAL GUIDE TO HARMONIZED FISHERIES DATA COLLECTION,  
INTERPRETATION AND MANAGEMENT

**OLRAC SPS**

[www.olsps.com](http://www.olsps.com)



**FISHERIES MANAGERS' TRAINING GUIDE:**  
**A TECHNICAL GUIDE TO HARMONIZED FISHERIES DATA COLLECTION,**  
**INTERPRETATION AND MANAGEMENT**

**Prepared by:** Pete Fielding, Amos Barkai and Shana Mian.

**Edited by:** Dr. Mohamed Seisay, Dr. Aboubacar Sidibe and Dr. Simplicie Nouala

**Disclaimer:** The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the African Union Interafrican Bureau for Animal Resources (AU-IBAR).

**Citation:** AU-IBAR 2016. FISHERIES MANAGERS' TRAINING GUIDE: A Technical Guide to Harmonized Fisheries Data Collection, Interpretation and Management. AU-IBAR Reports

All rights reserved. Reproduction and dissemination of material in this information product for educational or other non-commercial purposes are authorized without any prior written permission from the copyright holders provided the source is fully acknowledged. Reproduction of material in this information product for resale or other commercial purposes is prohibited without written permission of the copyright holders.

Published by AU-IBAR, Nairobi, Kenya

Copyright: © 2016 African Union – Interafrican Bureau for Animal Resources (AU-IBAR)

**ISBN 978-9966-1659-5-4**

Requests for such permission should be addressed to:

The Director

African Union – Interafrican Bureau for Animal Resources (AU-IBAR)

Kenindia Business Park

Museum Hill, Westlands Road

P.O. Box 30786

00100, Nairobi, KENYA

Or by e-mail to: [ibar.office@au-ibar.org](mailto:ibar.office@au-ibar.org)



## TABLE OF CONTENTS

<b>ACKNOWLEDGMENTS</b>	<b>vi</b>
<b>FOREWORD</b>	<b>vii</b>
<b>1. BACKGROUND AND RATIONALE</b>	<b>1</b>
1.1. THE AFRICAN FISHING ENVIRONMENT	2
1.2. FISHERIES IN THE AFRICAN UNION	4
1.3. SUSTAINABILITY AND NATURAL RESOURCE USE	11
1.4. THE STATUS OF AFRICAN UNION FISHERIES	15
1.5. GENERAL ROLE OF DATA IN FISHERIES MANAGEMENT - WHY COLLECT DATA?	16
<b>2. DATA AND INDICATORS</b>	<b>17</b>
2.1. OPERATIONAL INDICATORS	18
2.2. FISHING INDICATORS	18
2.3. BIOLOGICAL INDICATORS	18
2.4. ECONOMIC INDICATORS	19
2.5. SOCIO-CULTURAL INDICATORS	19
2.6. STANDARDISATION	19
2.7. DATA COLLECTION STRATEGIES	20
2.8. WHAT DATA SHOULD BE COLLECTED?	22
2.9. HOW SHOULD DATA BE COLLECTED?	23
<b>3. SYSTEMS AND TECHNIQUES USED TO MANAGE FISHERIES</b>	<b>39</b>
3.1. METHODS USED TO DECIDE HOW MUCH CAN BE HARVESTED	40
<b>4. COMMON STOCK ASSESSMENT PROCEDURES AND THE DATA REQUIRED TO UNDERTAKE THEM</b>	<b>41</b>
4.1. THE INEVITABLE AND THE PREVENTABLE IN MANAGED FISHERIES	41
4.2. QUANTITATIVE CONCEPTS IN THE MANAGEMENT OF LIVING RENEWABLE RESOURCES	43
4.3. OVERFISHING	48
4.4. MANAGING FISHERIES	49
4.5. METHODS OF FISHERIES MANAGEMENT	50
4.6. OPERATIONAL MANAGEMENT PLANS (OMPS)	51
4.7. CONCLUDING REMARKS	53
<b>5. HOW SHOULD THE DATA BE MANAGED?</b>	<b>54</b>
5.1. WHAT IS A DATABASE?	55
5.2. TABLES, RELATIONS AND QUERIES	55
<b>6. PROPOSED DATA MODEL FOR AU FISHERIES</b>	<b>59</b>
6.1. WHY WOULD YOU CHOOSE TO USE A DATABASE SYSTEM?	59
<b>7. REFERENCES</b>	<b>60</b>
<b>APPENDIX I</b>	<b>61</b>

## **ACKNOWLEDGMENTS**

The Director of AU-IBAR wishes to thank all those who have contributed to the preparation of this document. This includes member states of African Union, Regional Fisheries Bodies, other stakeholders and institutions that provided relevant information and all those who facilitated the work of this consultancy. Special thanks go to the consultants who prepared the document and the team at IBAR for the editorial work.

This work was done under the project '**Strengthening Institutional Capacity to enhance governance of the fisheries sector in Africa**' Project number, DCI-FOOD 2013/331 -056, funded by the EU to whom we are grateful for the financial support.

## **FOREWORD**

The availability of reliable data is one of the main prerequisites for informed decision making in fisheries and aquaculture sector. An importance area of weakness in a number of fisheries management regimes across the continent is the absence of informed decision-making in fisheries management. The reasons frequently attributed to this observation include the poor capacity to implement appropriate data collection systems and/or accurate interpretation of scientific information to formulate policies and control measures for rational fisheries management. In most cases therefore on the continent, fisheries management decisions are taken in arbitrary manner without reference to status of exploited stocks in the EEZs of coastal countries, lack of socio-economic consideration in decision-making etc. The visible signs of this weak capacity are clearly manifested by the current perturbed status of exploited fish stocks, often poorly negotiated fisheries access agreements rendering incommensurate returns, ineffective participation in international forums like Regional Fisheries Management organizations including lack of proper understanding with regards to compliance issues and criteria for quota allocation, weak information for effective advocacy to support growth in the sector.

The African Ministers at the 2014 Joint ministerial conference of Agriculture, Rural Development, Fisheries and Aquaculture recognized this gap on the continent and therefore urged the Member States to build capacity for collection, analysis and interpretation of biological, social and economic data for improved decisions making in fisheries management and aquaculture development. The development of this Guide is therefore within the overall implementation framework of the African Union Fisheries policy framework and reform strategy for fisheries and aquaculture in Africa. This pan African policy document has a major policy objective on conservation and sustainable use of fisheries resources that partly aims at strengthening the scientific and socio-economic basis for rationale fisheries management and aquaculture development.

The purpose of this Training Guide is primarily to equip Senior Fisheries Managers in the AU member states with the requisite knowledge and skills to recognize, appreciate and interpret fisheries bio-statistical, economic and social science data and information for informed decision making for the rationale management of the sector. To strengthen information sharing and comparison, the Guide also provides a framework for harmonization of data collection systems. The utilization of this training manual provides real opportunity to the AU member states for tackling some of the critical issues resulting from lack of implementation of sound and evidence-based decisions in the sector.

I wish to express the appreciation of African Union to the consultant, OLRAC SPS, and all those that contributed to the development of this Senior Fisheries Manager's Training Guide. The support of the European Union to the AU Fisheries Governance Project, under which this study was funded, is duly acknowledged.

**Prof. Ahmed El-sawalhy**

*Director of AU-IBAR/ Head of Mission*





## **1. BACKGROUND AND RATIONALE**

Fishery resources are of great social and economic value to Africa. The fisheries sector as a whole employs 12.3 million people as full-time fishers or full-time and part-time processors, representing 2.1 percent of Africa's population between 15 and 64 years old. Approximately 200 million people – or about 30 % of the continent's population - eat fish as their main source of animal protein and micro-nutrition. Fisheries also provide livelihoods for over 12 million Africans, many of whom are small-scale operators supplying food to local and sub-regional markets.

The policy framework and reform strategy for fisheries and aquaculture in Africa emphasized the conservation and sustainable uses of fisheries resources as well as enhancing capacity as key policy pillars. The Pan African strategy for fisheries data collection, analysis and dissemination was developed by the NEPAD, FAO and African Union and is intended to provide a framework and guidelines that should lead to improvements in the availability and quality of national and regional data to support fisheries management, aquaculture development and policy development.

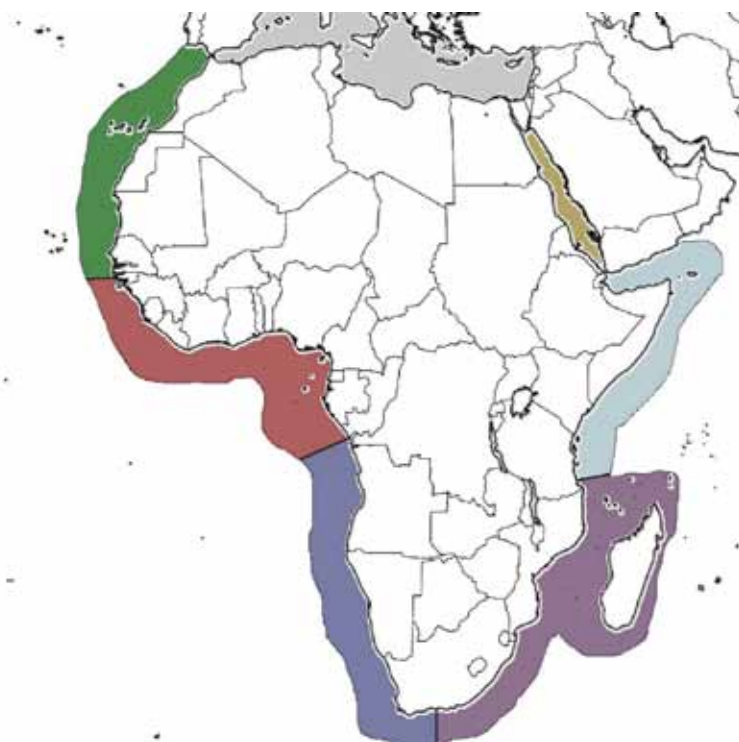
In the course of the development of the Strategy it was recognised that “African fisheries and aquaculture data-collection systems are not performing satisfactorily, and do not deliver all the information required for assessing the appropriateness of fisheries and aquaculture policy and management decisions, and for tracking the status of exploitation of fishery resources and the overall performance of existing fishery management measures”. The availability of reliable data is one of the essential requirements for informed decision-making in the management of fisheries.

Currently various AU member states with fishing sectors collect a variety of data related to their individual fishing processes but the collection methods, the type of data collected, the analyses and the interpretations and the capacity of staff to carry out these tasks in many cases do not achieve useful fisheries management objectives. In addition, the data and their collection differ so widely between countries making meaningful comparisons between similar fishing sectors in different countries impossible. Perhaps more importantly, it is impossible for different countries to share information that might be relevant to joint assessments of the status of stocks or the extent of resource use, or that might relate to any of the other parameters that could improve the management of individual or shared fisheries. A key issue is the need for harmonised collection, storage and analysis of fisheries data within regions and sub-regions across the entire AU region. This training manual and the training course associated with the manual are aimed at improving the understanding of fisheries in the AU and in particular the following issues:

- The need to implement science-based fisheries management for informed decision-making
- The areas in which fishing activities occur in and around Africa
- The scale, type and operation of fishing activities in the countries of the AU and the various resource users
- The idea of sustainability in relation to the use and management of natural resources
- The status of many of the fisheries associated with countries of the AU and the need for management of the fisheries to achieve sustainability
- The systems and techniques used in fisheries management
- The general role of data in the management of fisheries
- The kinds of data that can be collected, where and how data can be collected and stored, and the common problems associated with data collection and storage

- The ways in which data can be analysed to help understand the dynamics of a fishery and provide a rationale for management actions

Because of the scale and diversity of fisheries activities on and around the African continent, data collection and the harmonisation of data will be problematic for the foreseeable future, despite the existence of a data collection model developed to standardise data input. Therefore the training manual is developed on the principal that unless data collectors, analysts and fisheries managers have a basic understanding of the African fishing environments and the way in which fishing and data collection activities are conducted in those environments, they will be unable to properly understand the logistics of data collection and storage, nor will they be capable of conducting informed assessments of the quality of the data and the outputs of any analyses.



**Figure 1:** A schematic diagram of the Large Marine Ecosystems (LME) surrounding the continent of Africa. **Blue area** Benguela Current LME, **Red area** Guinea Current LME, **Green area** Canary Current LME, **Grey area** Mediterranean LME, **Orange area** Red sea LME, **Light Blue area** Somali Current LME, **Purple area** Agulhas Current LME.

### 1.1. THE AFRICAN FISHING ENVIRONMENT

From a marine fisheries perspective, the continent of Africa is surrounded by seven Large Marine Ecosystems (LMEs).

#### West coast LMEs:

- *The Benguela Current LME*
  - » Driven by the Benguela current which flows along the coast of south-western Africa, and its influence stretches from the Cape of Good Hope (South Africa), into Angola and sometimes as far as Luanda.
  - » It is a major eastern boundary coastal up-welling system and one of the most productive and bio-diverse ocean areas in the world.
- *The Guinea Current LME*

- » Flows south and eastward from Guinea Bissau to Gabon in the south and includes a range of coastal habitats such as lagoons, bays, mangrove swamps as well as 12 major estuaries and river systems.
- *The Canary Current LME*
  - » Major upwelling region off the coast of north-west Africa.
  - » Strongly influenced by the Canary Current.
  - » There are extensive mangrove habitats along the coasts of the southern states.

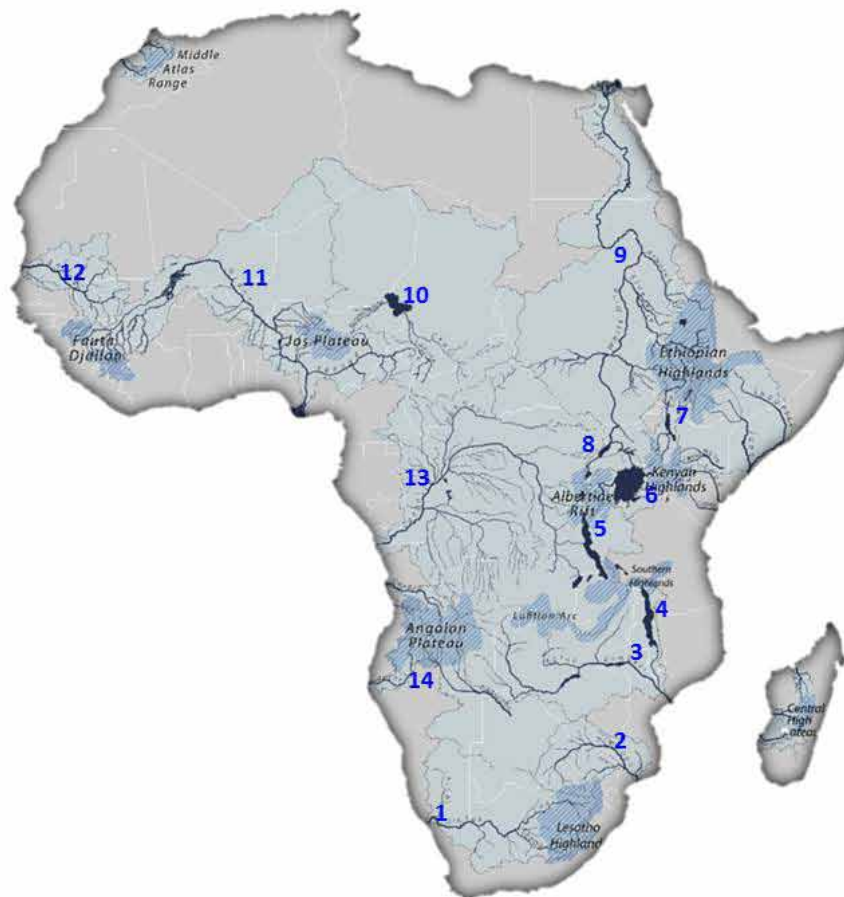
#### **North coast LMEs:**

- *The Mediterranean LME*
  - » Semi-enclosed sea with a number of distinct bio-geographical units.
  - » Local areas of upwelling and but it is considered a low productivity ecosystem.
  - » Northern Africa also has a number of large freshwater basins. The Nile basin is the largest of these.
- *The Red Sea LME*
  - » Highly saline, warm system with a complex oceanography.
  - » Deep layer highly saline outflows in winter are balanced by surface inflows of less saline water and these are impacted by the Arabian monsoon in summer.
  - » The system is considered a highly productive as a result of phytoplankton blooms in winter and the large extent of coral reef systems, mangroves and seagrass beds.

#### **East coast LMEs:**

- *The Somali Current LME*
  - » Summer upwelling and high productivity during the south-west monsoon.
  - » Current reversal takes place in winter during the north-east monsoon and upwelling is much reduced.
  - » There are very limited freshwater bodies inland of Somalia but extensive inland fisheries in Kenya and Tanzania.
- *Agulhas Current LME*
  - » Driven by the Agulhas current which is one of the largest western boundary currents in the world.
  - » The current is a major driver of the inshore and offshore ecology from Madagascar past Mozambique and down the east and south coasts of South Africa to the Agulhas Bank and the area of retroflexion.
  - » There are a number of inland fisheries associated with the countries bordered by the Agulhas Current LME.

With regard to the inland water bodies of the African continent, the freshwater lakes are mainly located on the eastern side of the continent and the resources of the larger lakes (the Great Lakes) are often shared by several countries. The western side of the African continent is not as well supplied with lakes as the east but there are a number of large rivers in the west and a multitude of smaller rivers that criss-cross the continent and provide water and associated resources to the people of the different countries through which they pass.



**Figure 2:** Map illustration the major lakes and rivers on the continent of Africa. 1=Orange R.; 2=Limpopo R.; 3=Zambezi R.; 4=Lake Malawi; 5=Lake Tanganyika; 6= Lake Victoria; 7=Lake Rudolph; 8=Lake Albert; 9=Nile R.; 10=Lake Chad; 11=Niger R.; 12=Senegal R.; 13=Congo R.; 14=Okavango R.

**Discussion** - What is a Large Marine Ecosystem – how is it defined? What are the main characteristics of the LMEs described above?

**Discussion** - of existing joint regional fisheries policy and management initiatives. From a data collection and analysis perspective it is important that representatives of different countries are aware of joint regional activities.

## 1.2. FISHERIES IN THE AFRICAN UNION

Fishing is an ancient activity on the African continent and dates back at least 40 000 – 60 000 years. The fisheries sector has continued to grow in importance both at an industrial level and at an artisanal/subsistence level. In virtually all the countries of Africa, catches in the artisanal sector far exceed catches in industrial sector in terms of total production. In terms of food security the artisanal sector is of particular importance in Africa because of the endemic poverty throughout the region.



**Figure 3:** Images of ancient fishing methods in Africa a) Woman and child using traditional woven fishing basket to catch fish on the Okavango, Botswana, b) El Molo man fishing on Lake Turkana, Kenya and c) Fish traps used by local fishermen in Kosi Bay, South Africa

**Table 1:** Fisheries production and number of people employed in various fishing sectors in the African Union. (% W) in brackets indicates the percentage of women in each sector.

No. Employed in Sector			Marine Production (t)	Freshwater Production (t)	Aquaculture Production (t)	Food commodity value USD
No. Fishers	No. Process.	No. Aquaculture				
6.2×10 <sup>6</sup> (3.6% W)	5.2 × 10 <sup>6</sup> (58% W)	0.9 × 10 <sup>6</sup> (4% W)	5.7 ×10 <sup>6</sup>	2.7 ×10 <sup>6</sup>	1.5 ×10 <sup>6</sup>	5 billion

### Activity 1.1

Small Group discussion, presentation and further discussion. (Groups constituted on a regional basis).

In Africa the fisheries sector continues to grow in importance both at an industrial level and at an artisanal/ subsistence level. In groups prepare a brief presentation to the rest of the class where you address the following:

- What fisheries (commercial, artisanal, subsistence, recreational) are found in our countries?
- What is the most important sector? Why is it the most important?
- Who else is involved in these fisheries (including markets and consumers)?
- How far inside /outside your country are these fisheries important?
- What sort of data do you collect in these fisheries
- Why do you collect these data? What use do you make of the information?

In the discussion it is important to link this activity to the data requirements for managing fisheries.

This west coast of Africa is one of the most economically important fishing zones in the world, producing about 4.5 million tons of fish. Namibia and South Africa are major fishing nations of the west coast and export large proportions of their catches. The Eastern African countries of Eritrea, Djibouti, Somalia, Kenya, Tanzania and Mozambique have well-established fisheries in the Red Sea and Eastern Indian Ocean but except in Somalia, there is a lack of the dense aggregations of small pelagic fish like sardines and anchovies which characterise upwelling areas. Tuna are caught throughout the region and are the main focus of fisheries in the island states of the African continent (Seychelles, Mauritius, Comoros) and the offshore fisheries of the West African coast. Throughout the continent small scale marine fisheries target a huge array of resources including large and small



species of finfish, molluscs, crustaceans, sea urchins, sea cucumbers and sea squirts. In terms of the value and numbers of people involved in fishing activities the small scale fisheries greatly outweigh the industrial fisheries.

Africa's inland fisheries in the lakes and rivers of the continent target a very wide range of species (>3000) and account for two-thirds of global inland fish production. Lake Victoria is the most productive freshwater fishery in the world, producing more than 500,000 tons of fish worth \$600 million every year. Unlike marine fisheries, the catch from Africa's inland fisheries is not exported out of Africa although there are industrial level fisheries in some countries. The catch is consumed almost entirely on the continent, forming a major source of peoples' protein intake.

### 1.2.1. The scale, type and operation of fishing activities in the countries of the AU

#### Activity 1.2

Small Group discussion, presentation and further discussion.

In groups prepare a brief presentation to the rest of the class where you address the following:

- Who are the fisheries resource users in your countries?
- How do you define or categorise the various groups of resource users?
- What are the resources targeted by each sector? Describe three for each sector.
- What fishing gears do the various resource user groups use? Describe the operation of three fishing gears used in each sector.

In the discussion it is important to link this activity to the data requirements for managing fisheries

#### 1.2.1. Who are the fish resource users?

Users of natural resources can be broadly classified into four distinct groups, namely commercial or industrial users, recreational users, artisanal and subsistence users. **It is important to be able to distinguish between these user groups, as each exerts different pressures on the resources they exploit and often need very different forms of legislation and management.**

##### Commercial or Industrial Resource Users

- Catch for profit and capital-intensive
- Large vessels, highly mechanised gear
- Range from small private enterprises to large scale industrial companies.

##### Recreational Resource Users

- Catch for leisure and sport.
- Big group in Southern and East Africa, growing in West Africa.
- Generally angling is a consumptive activity but catch and release is gaining momentum.



##### Subsistence and Artisanal Resource Users

- Difficult group to classify because there is such a wide range of users that can fall into this category.
- Members of this group rely on marine resources for their general day-to-day living.
- Artisanal fishers can be defined as those that are conducted by fishing households (not commercial)



companies)

- Subsistence fishers share and eat catch within family group and relatives of the fishers rather than selling catch.
- Some days a subsistence fisher might be acting as an artisanal fisher and on other days an artisanal fisher's catch may be entirely consumed by his family.



Although the general management of these various fishing sectors may need different approaches in terms of policies and regulations, one of the important issues is that the vessels that the various sectors use are very different. The International Standard Statistical Classification of Fishery Vessels (ISSCFV) is provided in Definition and classification of fishery vessel types (FAO Fisheries Technical Paper No. 267) and should be used as basis for vessel definition. Vessel type descriptions can be further refined with other data such as length, fish finding equipment, gross tonnage, engine power and other means of propulsion.



### **Overview of fishing vessels (FAO Classification of fishery types)**

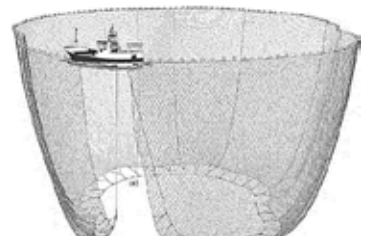
#### *Trawlers*

- Uses trawls as gear and have powerful engines
- Have winches to haul the net on-board
- Range in size
- Can be done using one or two vessels
- General discussion of trawler operation.



#### *Seine vessels*

- Use surrounding and seine nets set around a pelagic shoal
- Seine vessels range in size
- On boats and canoes using small seine nets, all operations are generally performed by hand
- General discussion of seine operation.



#### *Dredging vessels*

- Use a dredge (a rigid fixed frame structure with a basket attached to the back end) for collection of molluscs along the bottom.
- The power requirements are therefore substantial.
- Lifting gear is normally required to lift the dredge on-board.



#### *Lift netting vessels*

- Lift nets, which are held out from the ships side like a large upturned basket
- They are raised and lowered by means of outriggers.
- Powerful lights are often used to attract fish.

### Gill netting vessels

- Operated from a wide range of vessels fishing in inland waters, coastal and offshore waters.
- Operated from a wide range of vessel sizes.
- Vessels have two sub-categories – drift netter and set netters.

### Trap setting vessels

- Target lobsters, crabs, crayfish and other similar species.
- Vessels range from canoes to large decked vessels.
- Larger trap setting vessels are equipped with derricks, or cranes for setting and hauling of traps while on smaller vessels winches may be used.



### Lining fishing vessels

- Use lines and hooks with or without bait.
- Line fishing boats comprise vessels of all size classes
- Line fishing is the simplest and most widespread way of catching fish.



### Vessels using pumps

- Are used to suck small shoaling fish out of the water.

## Multi-purpose vessels

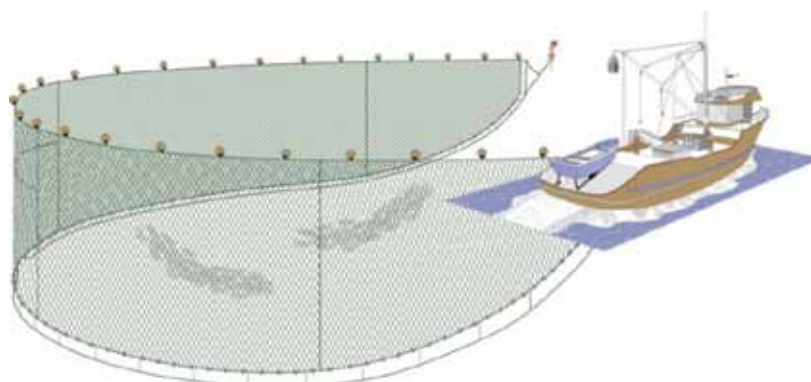
### Mother ships

There are also a number of other vessel types classified by the FAO that are associated with fisheries but not directly related to the capture of fish. These include hospital ships, research vessels and fishery protection vessels.

### 1.2.3. How are fish captured?

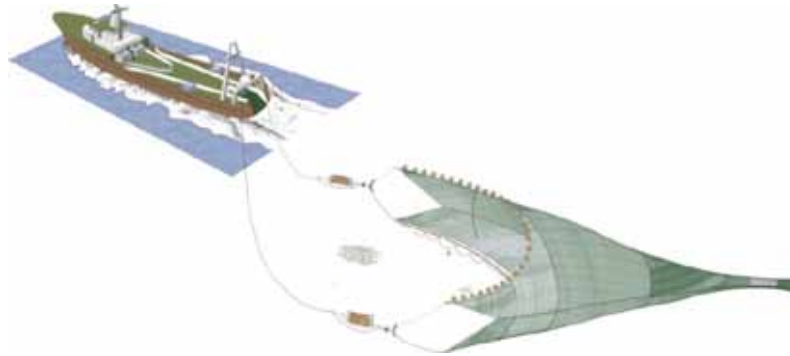
We have noted in the previous section that fish resources in the marine environment are exploited by industrial or semi-industrial fleets as well as by the artisanal and subsistence sectors. Industrial fleets use a wide variety of fishing gears that include purse seine nets, demersal and shrimp trawls, gill nets, long line fishing, and trap fishing. Artisanal and subsistence fisheries are highly diversified and use a wide range of fishing gears that includes gill nets and small scale purse seine nets, beach seines, cast nets, spears, a range of trap types, as well as lift and scoop nets. Some of the common fishing gears used by all sectors are identified below.

### Purse seine fishing



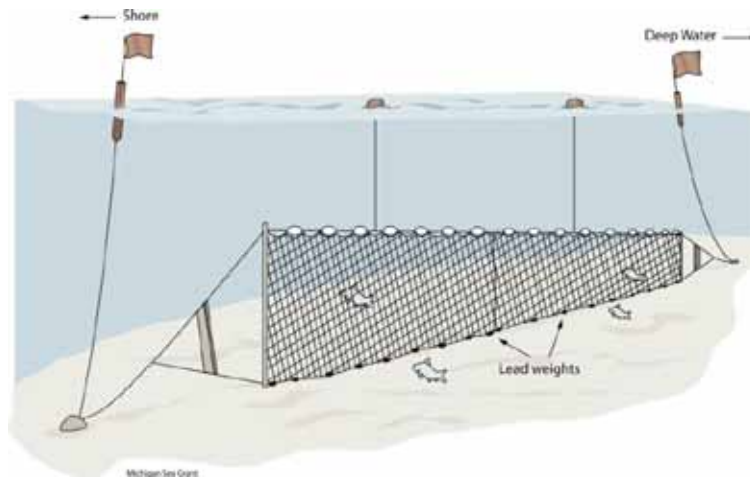
**Figure 4:** Illustration of a generic purse seine fishing method and gear

Trawl



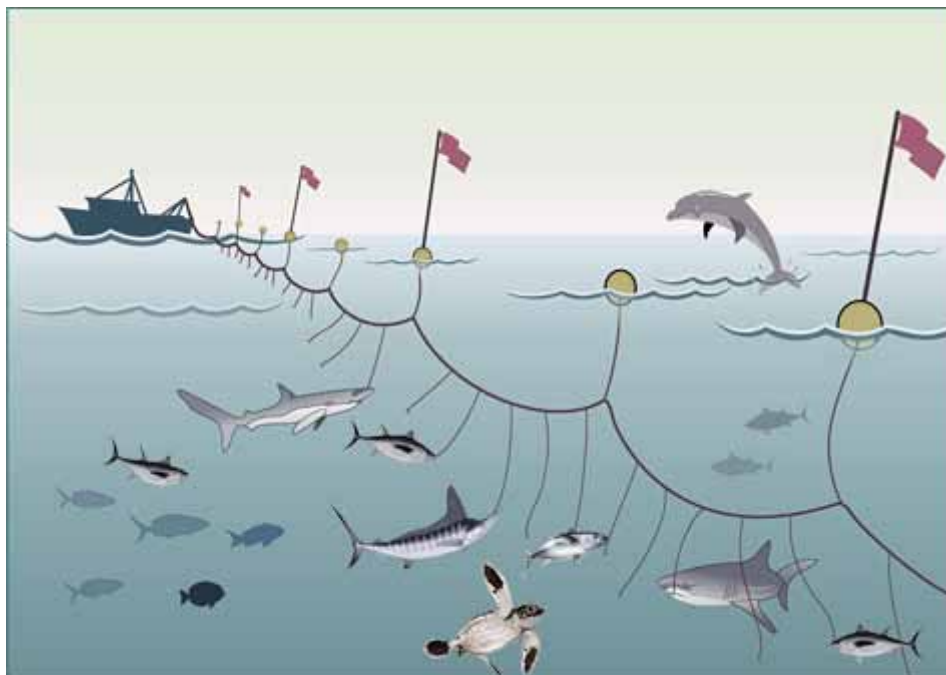
**Figure 5:** Illustration of a generic trawling fishing method and gear

Gill net



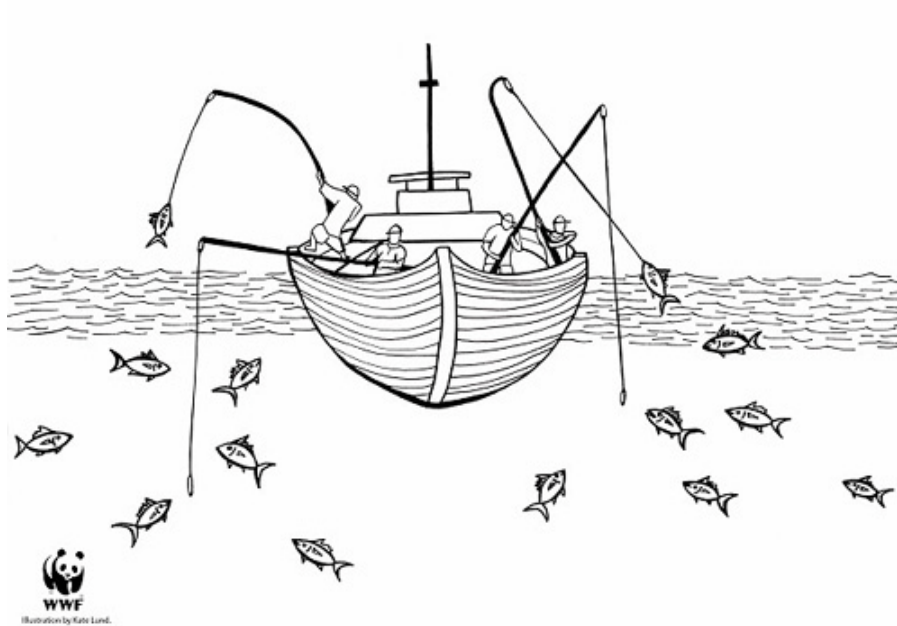
**Figure 6:** Illustration of a generic fixed gillnet fishing method

Long line



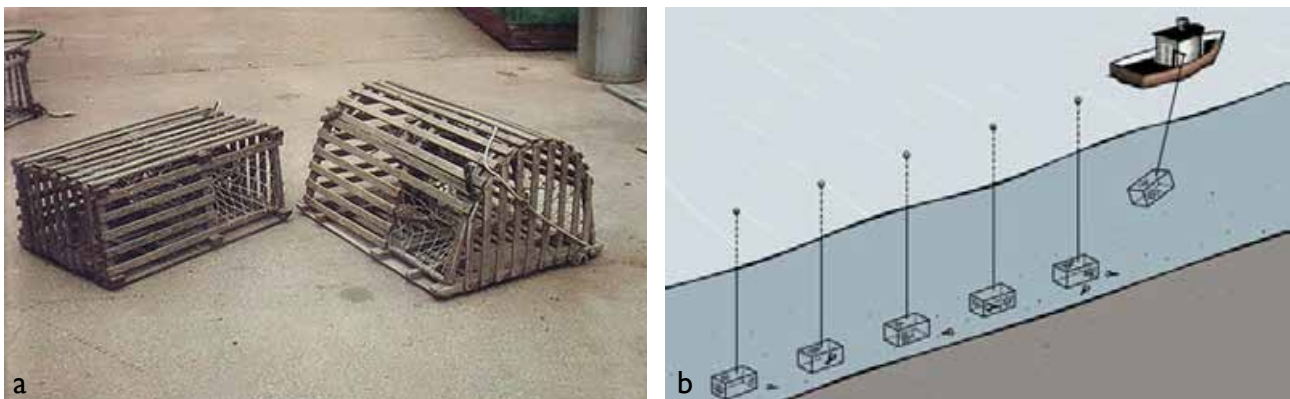
**Figure 7:** Illustration of a generic Pelagic/surface longline fishing method

## Hook and line



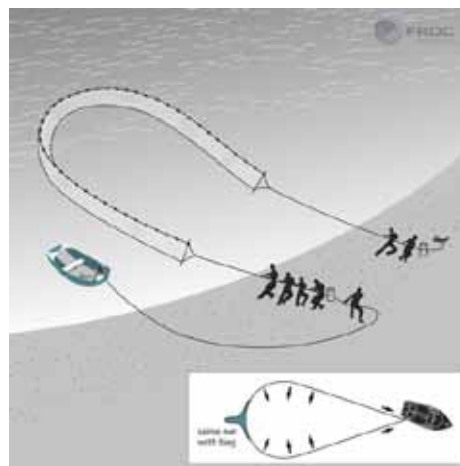
**Figure 8:** Illustration of generic hook and line fishing method

## Trap



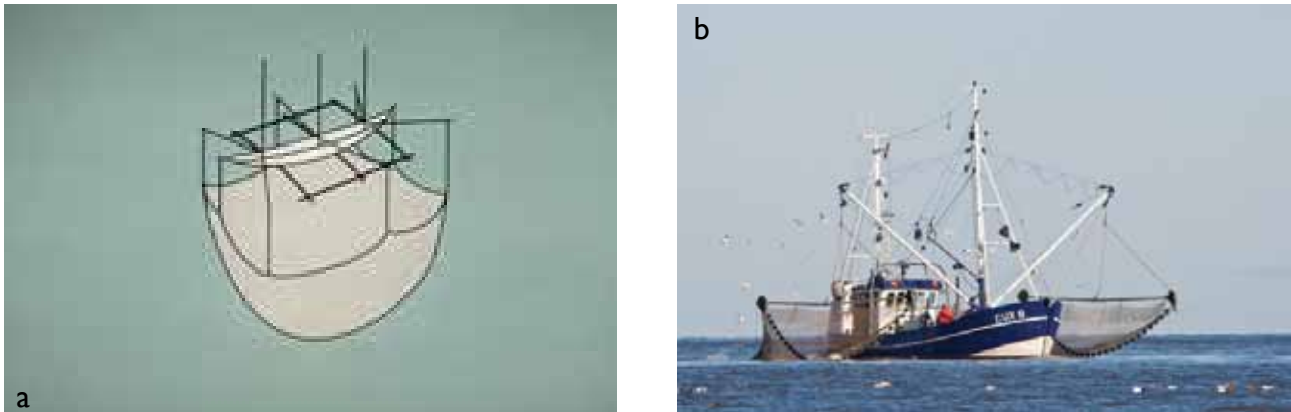
**Figure 9:** Illustration of a generic trap fishing methods a) showing a photo of a cage trap and b) the way in which these traps are set

## Beach Seine



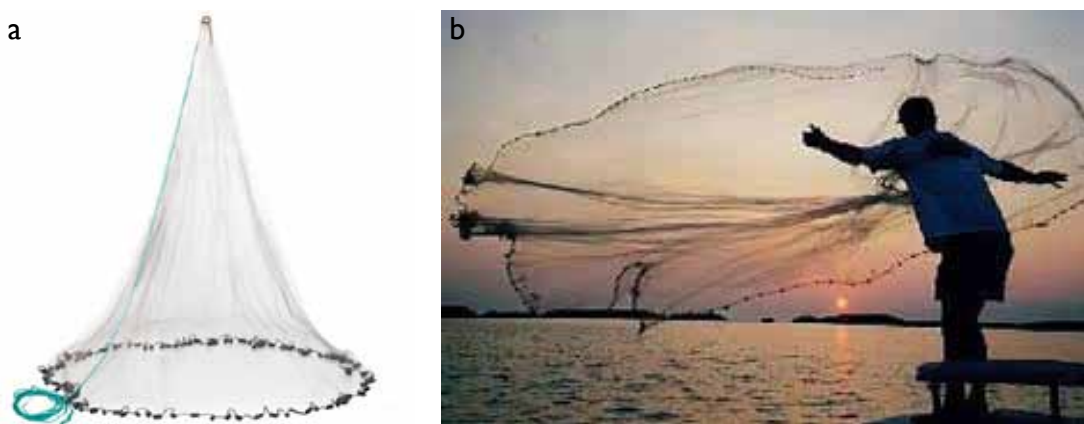
**Figure 10:** Illustration of a generic beach seine fishing method

Lift net



**Figure 11:** Illustration of a) a generic lift net fishing method gear type and b) vessel

Cast net



**Figure 12:** Photos of a) a cast net gear type used for fishing and b) fisher casting a cast net

As with fishing vessels it is critical to standardise the gear used in fishing activities if a common data capture and analysis model is to be implemented. The International Standard Statistical Classification of Fishing Gear (ISSCFG) is provided in Definition and classification of fishing gear categories (FAO Fisheries Technical Paper No. 222). Gear descriptions can be further refined with other data such as net length, mesh size, length of head rope etc.

### 1.3. SUSTAINABILITY AND NATURAL RESOURCE USE

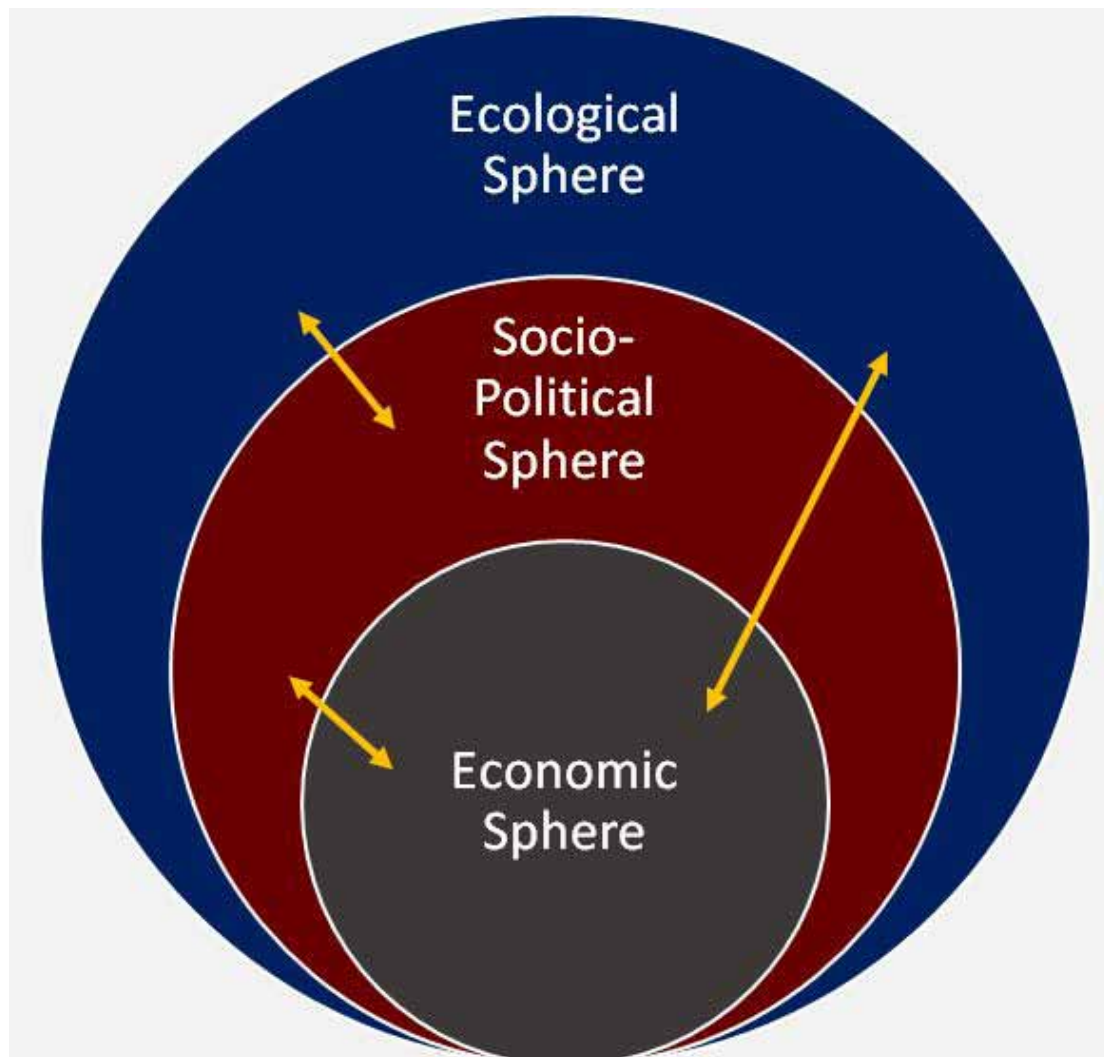
The word sustainability has become a common buzzword in recent years, relating to issues of development, the environment and our interaction with it. One of the most common contexts in which sustainability is used is that of 'sustainable development'. There are many definitions of sustainable development, including the landmark one the Bruntland Commission used in the 'Our Common Future' report in 1987:

“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Sustainable development has been described as the integration of the three e's — environment, economy, and equity



All our activities (economic, social and political) are 'nested' within the broad 'ecological' or environmental sphere on which everything depends. Damaging activities in either of the smaller spheres impacts negatively on the whole system. This model indicates that we need to think carefully about development in any form and the decisions we make for our futures.



**Figure 13:** Conceptual diagram of the various aspects of sustainability

#### 1.3.1. Aspects of Sustainability

- Ecological Sustainability
- Socioeconomic Sustainability
- Institutional sustainability
- Community sustainability

#### 1.3.2. Sustainable populations

A sustainable population is one that can persist through time by means of reproductive processes. In other words, if environmental conditions remain unchanged the population will be able to replace individuals lost as the result of predation, fishing, disease etc., with new individuals produced by members of the population. Environmental and ecological conditions can and do change and these changes may wipe out a population if it cannot adapt quickly enough. However, generally populations are wiped out because of man's unsustainable impact on living organisms rather than as a result of natural changes in the environment. From a management perspective it is important to understand



that over-fishing of a population is generally the result of recruitment over-fishing or growth overfishing. Recruitment over-fishing occurs when a stock is reduced to the point that not enough young fish are produced to ensure that the stock can maintain itself. It is quite logical that if no parent fish are left by the fishery no young fish will be produced.

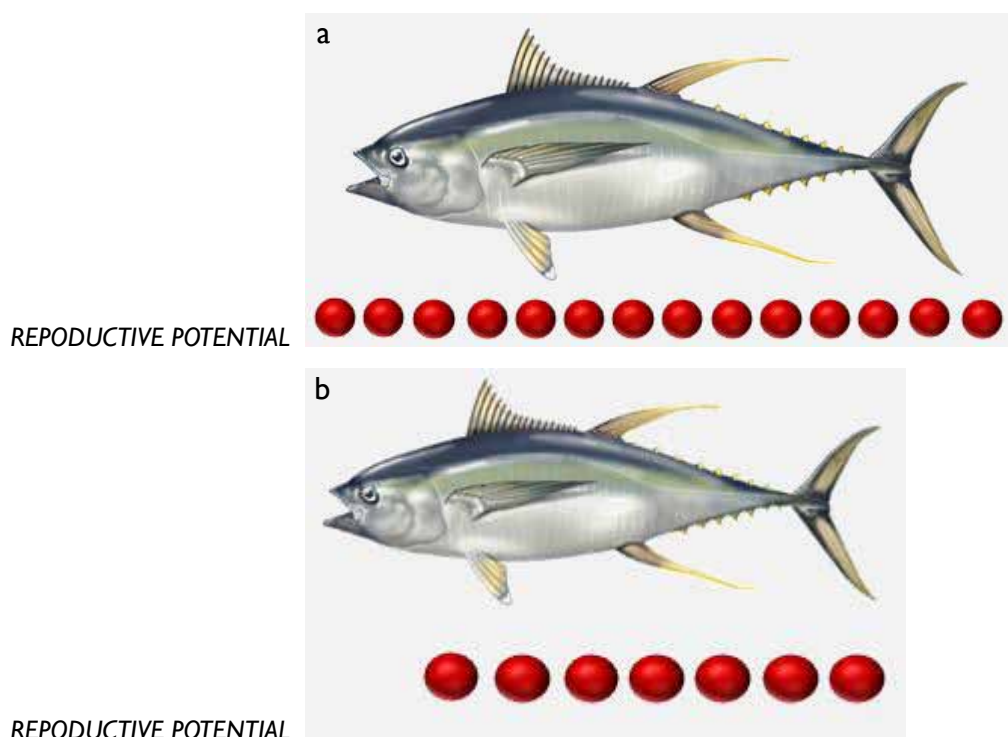
Growth overfishing occurs when young (small) fish are caught before they have a chance to grow to a size that would provide the optimum yield from a given number of recruits.

### 1.3.3. The Effects of Unsustainable Fishing

Apart from catching too many fish, unsustainable fishing practices can also be the result of negative impacts arising from fishing techniques that destroy marine habitats. Bottom-trawl nets with their rollers, trawl doors and foot chains can and do completely destroy bottom (benthic) habitats.

As populations of desirable fish become smaller because of over-fishing, there is a tendency for fishers to shift to other species (serial depletion), or to smaller size-classes of fish (often reproductively immature). This results in many individuals being removed from the population before they have a chance to reproduce which has a further negative impact on the population.

Removal of larger individuals can also cause changes in the population structure of exploited fish species. Heavily exploited populations of many species show shifts to a smaller size at maturity, or altered sex ratios (many fish species change sex at a particular size), both of which can have negative effects on reproductive potential for the populations. Smaller individuals of many species generally have a lower reproductive output than larger specimens. Larger fish carry many more eggs and these eggs survive better than eggs from smaller fish. If a species changes sex as it gets big, then if the large size classes are heavily exploited (which they usually are) there is a shortage of one sex for reproduction.



**Figure 14:** Illustration representing the difference in spawning potential between a) a larger versus b) a smaller sized fish

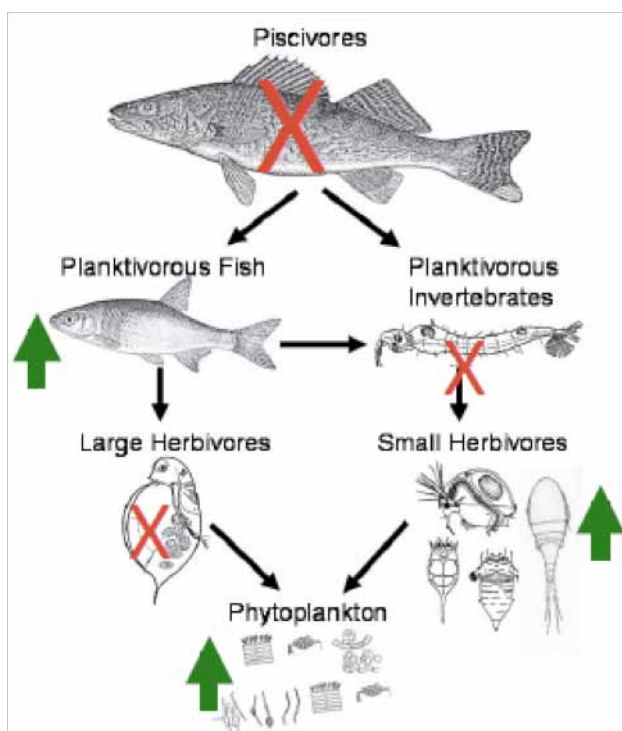
Over-fishing of some stocks of certain species can result in lowered genetic diversity of those species – the fast growing aggressive fish are caught first leaving slow growers behind.

A major problem in many fisheries is that of **by-catch** – the catching of non-targeted species that are usually discarded dead to make space for “useful” species. Global marine fisheries data conservatively indicates that by-catch represents 40.4 % of global marine catches.



**Figure 15:** Typical bycatch from a single prawn trawl. This catch is simply discarded overboard

The effects of unsustainable fishing practises can lead to a **loss of biodiversity** in marine ecosystems, but perhaps more importantly, the removal of a prey species or a predator species often causes large shifts in the abundance of the other species and leads to associated impacts on yet other species that they interact with. Such effects are often termed **trophic cascades**, where the removal of even one key species can have a huge effect on populations of several other species.



**Figure 16:** An example of a trophic cascade in the marine environment. The top predator in the system is fished down to very low levels, which results in a great increase in the number of smaller plankton eating fish. These small planktivores eat all the plankton eating zooplankton which results in an explosion of phytoplankton and very small herbivores and possible eutrophication if there is any nutrient input.

#### 1.4. THE STATUS OF AFRICAN UNION FISHERIES

##### Activity 1.3

Small Group discussion, presentation and further discussion.

In groups prepare a brief presentation to the rest of the class where you address the following:

- What are the most important fisheries in your area?
- Why are they important?
- What is the status of these fisheries?
- How do you arrive at your estimate of fishery status?
- Is the status of your fishery important?
- What can be done in practical terms to improve the status of these fisheries?

The populations in African countries continue to grow and as a result the demand for fisheries products continues to grow while the capacity of oceanic, coastal and freshwater fish stocks (including invertebrate stocks) to service this demand is limited by the population dynamics and ecosystem restraints of the various resources that are targeted. Over-exploitation and declining catches are a common theme for virtually all the fisheries (both marine and freshwater) associated with the African continent and it is estimated that fish stocks have declined by up to half in some coastal zones. This is of particular relevance to the nations of the AU where catches in the artisanal sector far exceed catches in industrial sector in terms of total production, and food security is a critical issue because of the endemic poverty throughout the region.

Critically, the poor quality of information relating to the management of fisheries has made it very difficult to formulate effective management policies and regulations at both national and regional levels. However, the artisanal fishery sector is the sector in most need of effective management

because it produces the bulk of the catch and it is so important in terms of food security, but it is the sector for which data are lacking or are most unreliable. Small Scale Fisheries (which consist almost exclusively of artisanal and subsistence fishery types) are catalysts of sustainable development in fisheries, but these fisheries must be properly managed if their impact on economic development is to be maximised and their benefits to the fishing communities of the continent are to be optimised.

### **1.5. GENERAL ROLE OF DATA IN FISHERIES MANAGEMENT - WHY COLLECT DATA?**

Management authorities need to have thoroughly evaluated the following questions before engaging in data collection programmes:

- Why do we need fisheries information? (Who are the users of the information and for what purpose is the information used?)
- What data do we need to collect in order to meet the requirements?
- How best can we collect the required data and information?

Data need to be collected for fishery managers to:

- Develop national (and multinational) policies
- Evaluate fisheries performance in relation to the predetermined management objectives
- Insure that fisheries managers meet Regional and International requirements

Fisheries data are central to the successful development of fishery management plans, policies and management strategies at both local and regional levels. Without reliable data it is simply not possible to manage a fishery in such a way as to derive optimal benefits, ensure its sustainability and engage in cooperative fisheries governance.



## 2. DATA AND INDICATORS

### Activity 2.1

Small Group discussion, presentation and further discussion.

In groups prepare a brief presentation to the class addressing the following:

- What data are collected in the industrial fisheries associated with your countries?
- What data are collected in the artisanal and subsistence fisheries associated with your countries?
- How are the data used?
- What data do you think should be collected in your industrial and artisanal fisheries?
- Why should these data be collected?
- What are likely to be the main problem issues with their collection?

Management related indicators refer broadly to the following issues:

- Status of resources
- Yield or fisheries production
- Fishing controls
- Economic efficiency or performance
- Social performance

In small scale fisheries in particular, it is critical to understand the economic and human dimensions of fisheries in order to manage them.

Quantitative methods for managing fisheries have become complicated but the quality and meaningfulness of their output depends entirely on the quality of the input data. Thus careful thought should be given to the data variables to be collected by answering questions such as:

- What are the main questions being asked of the fishery – are they resource use and sustainability issues, policy development issues, economic issues, social and cultural issues or compliance issues
- What stock assessment models should be used to assess and monitor resource status
- What are the logistics of collecting data

A very common mistake in fisheries data collection and monitoring programmes is the launch of a programme without proper consideration of what indicators the recorded variables can actually inform and whether the chosen indicators will provide the information required to resolve the issue(s) of concern. Indicators that help fishing authorities understand and manage fisheries can be broadly grouped into five categories. These are summarised here and discussed in more detail in the following sections.



## 2.1. OPERATIONAL INDICATORS

These indicators define the operational characteristics of fisheries. Data include vessel numbers and characteristics (vessel type, radio call signs, gear type, name, licence number, propulsion mode, engine power) for all fishery sectors are important operational indicators and trackers of fishing activities and patterns.

## 2.2. FISHING INDICATORS

There are numerous fishing indicators that are important. Catch in terms of total landed numbers or weight of fish is a key indicator that is used in the determination of several other indicators. Important elements of the total catch records are the species composition of the catch, the size structure of the component species, the gear or vessels used and the proportion of the catch that is discarded.

Effort is the indicator that is very widely used to set fishing controls in both small scale and industrial fisheries and it is an integral part of Catch per Unit Effort calculations.

Catch rate or CPUE is widely used as an indicator of stock abundance and depends for its usefulness on the quality of the catch and effort data.

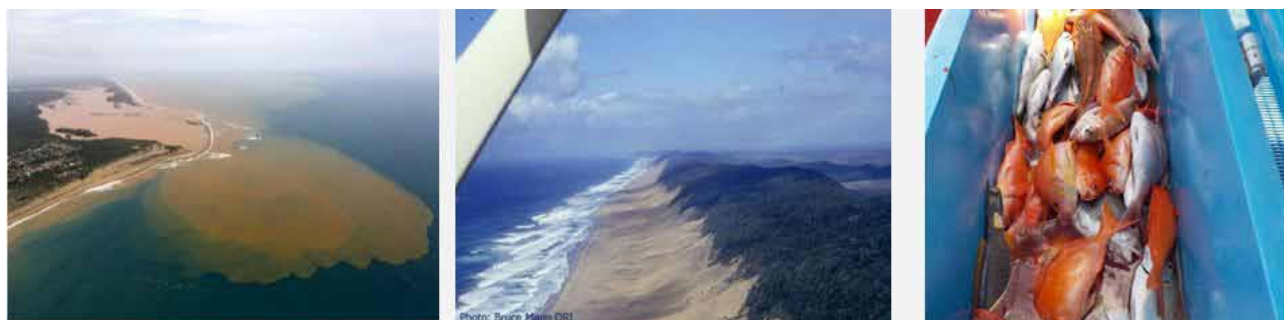
## 2.3. BIOLOGICAL INDICATORS

Sampling programmes that provide detailed information on the structure of a stock (mean size, age, sex, and maturity of captured fish,) provide input into stock assessments and greatly enhance the value of stock assessments.



**Figure 17:** Photo of fish being measured using a measuring board. Such sampling programmes provide detailed information about fish stock

Environmental data (oceanographic and meteorological) are useful because environmental variables are often linked to stock abundance and availability.



**Figure 18:** Oceanographic and meteorological data provide insights into stock abundance and availability by capturing conditions that affect stock abundance and availability



## 2.4. ECONOMIC INDICATORS

Economic indicators provide information about the monetary value of fishery activities and range from the gross value of the catch, to operational costs and earnings, management costs, foreign exchange earnings and the level of investment in the fishery.



Figure 19: Economic indicators provide insight into the economic value of the catch.

## 2.5. SOCIO-CULTURAL INDICATORS

Key indicators are the number of active fishers, the number of people involved in processing, marketing, sale and consumption activities and the number of households dependent on fishing for food or income.



Figure 20: Women form more than half of the labour force involved in processing and marketing fish resources in Africa.

The collection of data relevant to the indicators outlined above is a wide-ranging and generally expensive in terms of manpower, finance and infrastructure requirements like vehicles, boats, fuel, scales measuring boards and electronic data capture devices. **Where resources are limited, initial data collection should focus on the fish capture sector and more specifically on the measurement of catch and effort, the measurement of total catch weight and the recording of the relative proportions of the various species that make up the catch.**

## 2.6. STANDARDISATION

A critical element in the development of a common data collection programme across a number of countries is the necessity to agree on a common language for the recording and reporting of fishing information in general, and of catch and effort data in particular. The following data formats need to be standardised.

- Coding of latitudinal-longitudinal grid is standardised world-wide
- Weight should be measured in kilograms (kg) or metric tonnes (MT = 1000 kg)
- Length should be measured in metres (m) or centimetres (cm)
- Distance should be measured in kilometres (km)

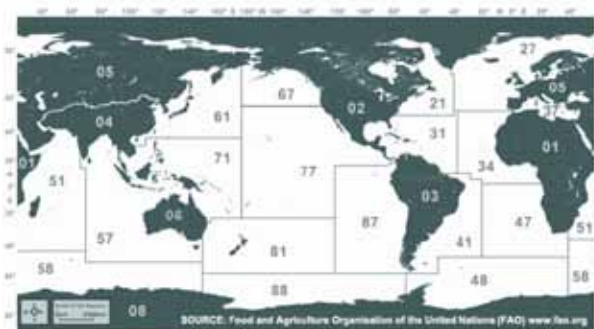
- Area should be measured in square metres (m<sup>2</sup>) or square kilometres (km<sup>2</sup>)
- Volume should be measured in litres (l) or cubic metres (m<sup>3</sup>)
- Electrical Power should be measured kilowatt-hours (Kwh)
- Horse Power
- Date and Time

The type and format of oceanographic and meteorological data that are recorded must also be standardised across the AU countries. These data include temperature (°C), wind speed (km per hour), salinity (ppt or ‰), precipitation (mm), conductivity (µS/cm), current speed (m per sec), wave height (m) and wave period (sec).

Countries need to agree to reference their catches to the internationally established FAO major fishing zones as indicated in the figure below. Countries should record geographic data identified by their FAO ISO3 Country Codes as indicated in the table below.

**Table 2:** Examples of the FAO ISO3 Country Codes for some African countries.

Country	ISO3 Code
Algeria	DZA
Angola	AGO
Benin	BEN
Botswana	BWA
Burkina Faso	BFA
Burundi	BDI
Cabo Verde	CPV



**Figure 21:** Internationally established FAO major fishing zones cover the marine and freshwater habitats of the world. AU countries fish in marine fishing zones 34, 37, 47 and 51 and all inland fishing takes place in fishing zone 1.

## 2.7. DATA COLLECTION STRATEGIES

Some variables need to be measured by complete enumeration (the entire population) and some must be measured by sampling programmes (only part of the population). One of the elements of a data collection strategy is to decide which variables need to be collected through complete enumeration and which should be sampled. Complete enumeration is expensive for many variables, but must be carried out for some variables (e.g. vessel registration, fishing infrastructure). Sampling is more cost effective, but is often subject to bias in the sampling process.

The other distinction that must be made in the collection of data is that of routine data collection and ad hoc data collection. Routine data collection systems should be robust and simple, and will provide the basic long-term data series on structure of the fleet, the number of fishers, the landing sites, catch and its composition, catch value and sometimes fishing effort. Ad hoc data are largely the result of scientific surveys or research programmes and provide information on recruitment, biomass, stock distribution, reproduction and growth information, the state of the ecosystem, livelihoods and earnings, gear specific CPUE etc. (de Graaf et al. 2015).

In general, the following will be required to develop a data collection strategy:

- Evaluate existing data sets in relation to the objectives of proposed fisheries management.
- Develop a good understanding of how the fishing sector operates as a whole
- Decide which variables must be completely enumerated and for which variables data can be collected by sampling.
- Design methods to collect data according to the approach adopted (sampling or complete enumeration).
- Implement a test phase to validate the method.
- Establish a feedback mechanism between data sources and data users to ensure that data types, quantity, quality and origin are consistent with the requirements for determination of the performance indicator in question (FAO 1999)

Although data collection methods should be designed to reduce variance and bias as far as possible, the implementation of any data collection strategy depends to a large extent on the budget and personnel available and on operational considerations. These factors rather than statistical considerations very often determine the extent and methods of data collection programmes. There are a number of ways to reduce bias in sampling programmes. It is particularly important to understand the principles of stratifying sampling effort, reducing sample variance as far as possible, estimating minimum sample size and avoiding bias (see De Graaf et al. 2015).

A key principle that all data collection strategies should keep in mind is that it is far more useful to collect a small amount of good data than to collect a lot of poor quality data. Always ask the question “what can I realistically collect with the available staff and budget”?



**Figure 22:** Characteristics of data that is of high quality

## 2.8. WHAT DATA SHOULD BE COLLECTED?

Each fishery will have its own set of problems when it comes to collecting data. Data collection programme designers and fisheries monitors have to understand local data capture problems and structure the data collection process in a way that makes the best use (in terms of useful data collected) of the resources available. It is for this reason that we keep stressing that it is critical to understand how a fishery operates before setting up a data collection programme. Data should be captured in a format that allows them to be used in the estimation of as many indicators as possible. At the same time the recording of data types is heavily dependent on the analyses that will be used to determine reference points in any fishery. Thus judgement regarding the format must be exercised in the planning stages. For these and reasons outlined above, **data collection should be carefully planned.**

There are many types of fishery data that can be potentially relevant to fisheries management. A fishing vessel (even an artisanal or subsistence fishing vessel) has certain properties that define its fishing capabilities and fishing strategies. There are multiple fishing gear specifications and gear deployment techniques which may affect fishing operations.

From a catch point of view, the catch may be made up of several different species, different sexes, different reproductive stages, age and sizes. Targeted fish live at different layers in the water column and in different habitats. There are almost always ecosystem impacts of fishing operations.

Harvested fish are processed and sorted by species, product, grade, size, weight, all of which information generally needs to be recorded in order to determine actual catch weight. Understanding the social and cultural environment within which fishing activities take place is critical to the management of fisheries and particularly artisanal and subsistence fisheries, so it is important to collect these kinds of data.

Some of the generic information which is used to formulate advice for fisheries management is listed below:

- What boats, equipment and individuals were engaged in fishing, and how, where and when were they fishing
- Catch and effort data –how much was caught, who caught it and how was it caught
- Environmental information - the prevailing oceanographic, riverine, lacustrine and meteorological conditions
- What species make up the catch
- What is the size structure and age structure of the various species of fish in the catch
- Gender, diet and reproductive information relating to the fish in the catch
- Data associated with tagging and recapturing fish
- Spatial and temporal information related to all of the above
- Biological sampling data – the observation of specific characteristics of a portion of the catch which can be used to define characteristics of the fished population. Typical biological data derived from a sampling programme include fish age, mean size, growth rate, size at maturity and fecundity, diet, condition, and sources of mortality not caused by fishing. Sampling from a catch is used to make generalizations about the state of the entire fish population. Catch sampling must be planned and executed to exclude bias and error.
- Bycatch information
- Product types and value
- The number of individuals engaged in fishing related activities and the extent and way in which such activities impact on their livelihoods.

## **2.9. HOW SHOULD DATA BE COLLECTED?**

Fisheries data can be sourced at several points in the fishery chain. Critical points include:

- Harvest where fish are caught and the catch is immediately recorded at sea
- Post-harvest where fish are landed and prepared for market
- Sale or Market transactions
- Consumers – where the product is consumed
- Government agencies outside the fishing industry (e.g. meteorology services, export agencies)
- Support industries that provide services to fishing activities.
- Scientific research

It is a good idea to crosscheck data by collecting the same data at two different points. For example total catch can be recorded at harvest and again at the landing site or where fish are marketed.

The main data collection methods are:

- Registration – usually with fishery authorities
- Questionnaires completed by targeted respondents
- Interviews – structured (questionnaire) and open-ended (free talk)
- Direct observations and recording by sea based and land based observers
- Reporting by fishers
- Surveys by fisheries management agencies
- Research programmes.

### **2.9.1. Structural Data**

We referred earlier to Operational indicators that define the operational characteristics of fisheries such as vessel numbers and characteristics (vessel type, gear type, name, licence number, propulsion mode, engine power, length, tonnage) for all fishery sectors - these data define the structure of a fishery. At an industrial level these data are completely enumerated. Additional data should include the skipper's and owner's name, the crew requirements and details of the technical and mechanical capacity (fish finding equipment, winches, power blocks, side thrusters etc.).

At the artisanal and subsistence level similar data should be collected but the information will be limited to the vessel type, gear type, length, the propulsion mode and power (if motorised) and the name of the owner/skipper/cooperative/licence holder. Fishing fleet characteristics are generally collected by way of surveys which may be conducted every year but more often every two or three years.

### **2.9.2. Operational data**

Details relating to the conduct of fishing operations should also be recorded where possible. At the industrial level the name and category of vessel, the skipper, the number of crew, the port of departure and offload, coordinates of fishing operations (start and end), time engaged in fishing, on anchor, searching, steaming, and the fishing gear in use should all be recorded in a logbook and entered into a database.

At artisanal and subsistence level it is likely that the number of vessels or fishers that set out, the length of time that vessels or individuals were away fishing, the general area or habitat in which they were fishing, the number of crew (if a vessel is used) and the gear they were using is probably



the extent of information that a monitor is likely to collect relating to the conduct of the fishing operations. Collecting operational data from artisanal and subsistence fisheries is not simple. The fleet setting out to sea will probably consist of a number of different vessel types. Some may be motorised and some may use sails or paddles. Engine sizes and crew numbers will vary. We stress again the importance of understanding the nature of a particular fishery and fishing community operations before planning and undertaking monitoring and data collection exercises.

Artisanal and subsistence operational data should be captured by direct observation and interviews with fishers at each landing site by a dedicated fisheries monitor on a prepared data sheet.

### 2.9.3. *Catch and effort*

Key fisheries data that must be collected in all fisheries are those related to the catch and the effort expended to make that catch

#### Activity 2.2

Small Group discussion, presentation and further discussion.

In groups prepare a brief presentation to the rest of the class where you address the following:

- What do you understand by the term Catch and by the term Effort in relation to fisheries?
- How are Catch and Effort linked? Why do fisheries managers like to collect catch and effort data?
- In the fisheries with which you are familiar, what are the problem issues in the measurement of Catch and Effort?
- How do you think these problems can be resolved?

Before we discuss the subject of Catch Per Unit Effort, it must be understood that Catch data and Effort data are the key information that make the calculation of the total catch possible. The main purpose for obtaining catch and effort data is for the calculation of catch rates or more commonly Catch Per Unit Effort (CPUE) which is often used as an indicator of resource abundance.

#### 2.9.3.1. **TOTAL CATCH**

Catch in terms of total landed numbers or weight of fish is a key indicator that is used in the determination of several other indicators. Important elements of the total catch records are the species composition of the catch, the size and sex structure of the component species and the gear used to catch it. The raw or green catch weight should be recorded when any vessel or fisher offloads a catch (routine data). In artisanal and subsistence fisheries, sampling to estimate catch weight is generally required (see below). Total Catch would be determined by multiplying an estimated CPUE by the effort or, over a longer period, by assessing the number of active fishing units, the average catch of a fishing unit and the number of days the fishing units operate. If an industrial catch is processed at sea, landed catch may need to be derived from production conversion factors. It is stressed here that it is critical to agree on a standardised measure of weight at a regional level for each individual fishery if regional management policies are to be developed.

Further requirements in this regard are the use of The Harmonised Commodity Description and Coding System (Customs Co-operation Council, 1992) for classifying traded fishery commodities (see World Customs Organisation). Many of these relate to industrial products but artisanal and subsistence product types fit some of the categories (gutted, boned, headed, fins off).

**Table 3:** Commercial product types that might need to be converted to total landed catch weight.

Product types	whole round/green; gutted; boned; headed; fins off; fillet; skin on/off; loin; mince; surimi; fish meal (from whole fish/discards/broken or sour/offal etc.); consumer packs
Product storage	whole frozen; IQF; hold frozen; storage temperatures; dry; brine; salted; fresh
Product packaging	individually marked and packed (e.g. tunas); carton (type and weight); bag (type and weight); basket (type and weight); barrel
Package contents	non-fish weight (ice, glaze, salt, packing material, coatings, liquids, sauces etc.); fish number; package weight; product type; size grade

It is important to capture the type and weight of any processed product so that total landed weight can be calculated for use in other calculations or comparison with data from other sectors or other countries.

### 2.9.3.2. EFFORT

Effort is the indicator that is very widely used to set fishing controls, particularly in small scale fisheries. There are a host of factors that define and impact on effort determination, particularly with respect to fishing gears, and as a result it is one of the more difficult indicators to standardise. When recording effort it is particularly important to standardise the units of effort so that CPUE estimates are comparable. At a primary level, an effort measure associated with each gear type must be defined. Standardised Fishing Effort Measures by Gear Categories have been suggested for the purpose of carrying out stock assessment in the Report of the Ad Hoc Consultation on the Role of Regional Fishery Agencies in Relation to High Seas Fishery Statistics (FAO Fisheries Report No. 500, 1993) and these should inform effort data collection in industrial artisanal and subsistence fisheries. If units of effort are not comparable across regions then it is impossible to compare evaluations of fishery status.

**Table 4:** Examples of how the FAO suggests effort related to different gears is evaluated (FAO Fisheries Report No. 500, 1993; See Appendix xx for the complete table)

Fishing Gear	Effort Measure Descriptions	Definition
Gillnets (set or drift)	Number of effort units (gillnets)	Length of nets expressed in 100 metre units multiplied by the number of sets made (= accumulated total length in metres of nets used in a given time period divided by 100).
Lift net	Number of hours fished	Number of hours during which the net was in the water, whether or not a catch was made
Traps (uncovered pound nets)	Number of effort units (traps)	Number of days fished x the number of traps hauled
Longlines (set or drift)	Number of hooks	Number of hooks fished in a given time period and the number of sets made in the course of the fishing trip

It is critical that data capturers understand that for all gears an effort unit should be recorded regardless of whether or not a catch is made. Effort measures can be modified to suit fishery specific purposes but the modifications must be agreed at the regional scale appropriate to the relevant fisheries. At an industrial level effort is generally recorded in a logbook and should indicate the type of gear used, the number of sets (trawls, longlines, gillnets, purse seines, traps, dredges) made and the time for which a set was active.

Standardising a unit of effort becomes very difficult when a stock is fished by many different kinds of gears. It is sometimes possible to relate all kinds of gear effort to a standard unit by undertaking comprehensive series of fishing comparisons. However, some gears are so different that comparisons are not possible.

As with the recording of operational data there will be complications in the measurement of effort in small scale fisheries. It is almost certain that effort estimates will be limited to the number of fishers or vessels operating per unit time for a gear type. It is unlikely that the number of sets made by an artisanal purse seine or beach seine will be recorded. There are unlikely to be records of the number of hooks on a longline or number of lifts of a trap or lift net. The fisheries monitor must understand the dynamics of the fishery and have a pre-determined, standardised approach to the recording of effort. When collecting these data there is no substitute for direct observation and monitoring.

### 2.9.3.3. **CATCH PER UNIT EFFORT OR CATCH RATE**

The standardisation of catch per unit effort (CPUE) data is possibly the most critical preliminary step for stock assessment analyses. Excepting fisheries for small shoaling pelagic fish species, in most fisheries and particularly trawl fisheries CPUE is one of the most important indicators of trends in resource abundance.

Catch rate in a fishery is the amount of fish caught per unit of time fishing per unit of fishing gear, and is often referred to as CPUE. Examples of fishing gear are: a rod and line, a fish trap, a throw net, a trawling vessel, a purse seine vessel.

#### **Typical units for catch rate or CPUE are therefore:**

- fish per angler per hour
- fish per fish trap per day
- number of fish caught per throw net per hour
- tons of fish landed per hour trawled per trawling vessel
- tons landed per day per purse seiner

Catch rate or CPUE is widely used as an indicator of stock abundance – the greater the amount of resource the higher the catch rate and conversely the smaller the resource biomass the lower the CPUE. The first sign that commercial fishing is having an impact on the natural population is that the catch rate starts to decline. It must be strongly emphasised that CPUE needs to be used with caution as it is a complicated parameter and its' usefulness as a resource abundance indicator depends very much on the quality of the catch and effort data.

In industrial fisheries it is quite feasible to assess CPUE based on the different gears that vessels are using. Catch rates in all industrial demersal trawl fisheries vary greatly from a few hundred kg of fish per hour to several tonnes per hour trawled. Shrimp trawl fisheries generally catch less than 100 kg of shrimp per hour trawled but may have considerable bycatch. Purse seine fisheries have similarly varied catch rates. A tuna purse seiner may catch from zero to 5 tonnes per set while a large anchovy purse seine vessel may catch 50 or more tonnes of fish per set. Tuna longliners in the WIO may occasionally catch as many as 3 or 4 fish per 100 hooks but generally the catch rate is very much less than one fish per 100 hooks. In artisanal fisheries, because of the very wide range of gears in operation on most fish resources and the lack of resources to conduct wide-ranging data collection, it is likely that CPUE will be estimated on a boat basis even though a gear based approach is generally

a better indicator. It must be emphasised that CPUE it is not a good indicator of stock size for small shoaling pelagic species. Discuss why this should be so.

### Activity 2.3

Small Group discussion, presentation and further discussion.

In groups prepare a brief presentation to the rest of the class where you address the following:

- Provide a brief explanation describing what you think CPUE is.
- Why do you think it is important to measure CPUE?
- How are you going to measure the CPUE of gillnet fishers catching Nile perch in Lake Victoria?
- How are you going to measure the CPUE of hook and line fishers operating in the inshore coastal regions of Angola?
- The factors you need to think about are the following:
- How are you going to measure effort in each fishing sector?
- How are you going to measure catch in each fishing sector?
- What fishing gears are in use in the gillnet fishery and how do they differ? What problems do you foresee in the data collection process?
- What practical measures can you take to overcome these problems to derive a unit of effort?
- What fishing gears are in use in the handline fishery and how do they differ? What problems do you foresee?
- What practical measures can you take to overcome these problems to derive a unit of effort?
- What problems do you think you might encounter when measuring the catch of the gillnetting in Uganda and the handline fishers in Angola?

#### 2.9.3.4. SPECIES DATA

Catch composition (species) and structure (mean size, age, sex, maturity) are important indicators of the status of a fishery. The first issue is to identify the species that make up a catch. Very few catches in any fishery are made up of only one species and the component species that make up the major part of the catch need to be identified.

Species: The identification and naming of fish species captured by different countries is a perennial problem in data collection. Different countries have different names for the same species of fish or two species of fish can have the same name. Sometimes one species of fish can have different names in different regions within a single country. With regard to fish species identification, the FAO International Standard Statistical Classification for Aquatic Animals and Plants (ISSCAAP code) should be assigned. The taxonomic code is used by FAO for a detailed classification of species items and for sorting them out within each ISSCAAP group. The ISO3 FAO Species Code should be used by all AU countries when recording catches. A monitor should be able to identify any fish species that forms more than about 5% of the catch. Species data should be routinely recorded on landings for every fishing trip that is monitored. The monitor will probably record the local name of fish captured but the ISO3 Species Code should be entered as soon as the data are electronically captured. There must be a register of local names matched to FAO codes for the data logger to refer to and confusions that exist regarding local species names and their FAO codes should be resolved before monitoring starts.

**Table 5:** Examples of the FAO Standard Common Names and Scientific Names for fish and the ISO3 Species Code. There are 12 600 items in the list.

Common Name	Scientific Name	ISO3 FAO Species Code
Malabar trevally	Carangoides malabaricus	NGS
Giant trevally	Caranx ignobilis	NXI

**Sampling:** When data cannot be collected for the entire fishery a part of the fish catch must be examined (a sample) and the results extrapolated to the entire fishery (the population). The way in which the sample is selected is critical to ensure that the sample is a good representation of the population. There are many factors that can cause bias in sampling and it is important to avoid bias because when samples are extrapolated to populations the entire assessment of the fishery can be catastrophically skewed if the sampling process is biased.

One way of avoiding bias is to take a random sample from a catch. With a random sampling programme, **all individuals (landing sites, vessels, fishers, fish) have an equal chance of being selected for assessment** and this criterion should be strictly observed as far as possible. The first question is to determine which landing sites should be monitored. However, in practice, monitoring resources are always limited and thus very often the landing sites sampled are selected because of geographic, administrative or habitat considerations.

The next issue is to determine which of the vessels arriving at a landing site or shore fishers arriving from a fishing expedition should be sampled. The important point is that the monitor should have no choice in the boats or fishers selected for sampling. However, what often happens is that the monitor has constraints on his/her time or enthusiasm. Catch monitors must be capacitated to understand the basic elements of reducing as far as possible subjective selections in data capture programmes.

**Sampling of a catch:** How do we obtain a random sample from the catch in the boat or in a fisher's bag? Getting sufficient access to the catch is often the most difficult part of a fisheries monitor's duties. At industrial fish are mainly frozen and sampling must be conducted in cold rooms, or fish are packaged in containers that are difficult to open. In small scale fisheries, fish are often stored and offloaded in boxes or crates and in practical terms the only way of randomising the sample may be to select a crate of fish at pre-determined intervals e.g. every tenth crate. However, care must be taken when selecting crates for sampling because the contents may not constitute a random sample of the fishing trip catch. Sometimes during the fishing process or on the way back to the landing site, fishers grade fish with regard to size, value, species etc. so when the boat reaches the shore, the contents of crates no longer represents a random fish sample. Another potential issue is that the fish in a catch box of a single boat might have been caught by two different gears. Alternatively, the boats randomly selected for sampling are actually using a variety of gears. There are also other pressures that often affect the availability of fish for sampling – fishers are in a hurry to offload, distribute the catch and ready the boat and gear for the next fishing trip, or buyers and processors are waiting to take the catch away. All of these factors can make the sampling of the catch a difficult process.



When sampling the catches of subsistence invertebrate collectors, there are also factors that can bias sampling. For instance catches should be sampled post-harvest rather than in the course of the collecting activity because the level of the tide generally affects the species and the size structure of organisms that can be collected. Catches should be sampled on the shore rather than at the village because part of the catch is frequently eaten on the shore. The selection of collectors and their catches to be sampled should be randomised as much as possible. Frequently there are multiple access and exit points to and from the shore and there may be distinctions (gender, age, food



preference, time factors) between collectors using the various access/exit points.

Clearly, bias in the sampling of the catch can arise as a result of a multitude of situations and it is important to remove it as far as possible. Again it must be stressed that the data collectors and those who design data collecting programmes must have a good understanding of the operational characteristics of the fishery.

The next question is how many fish of the catch need to be sampled in order to obtain a realistic estimate of the catch composition and useful size frequency and maturity information. De Graaf et al. (2015) provide a detailed description of the statistical basis of sampling design and the designers of data capture programmes need to understand the statistical basis on which sample size calculations are based.

**Variance and Stratification:** The sampling process involves the recording of a characteristic (e.g. length) of a small number of fish (e.g. five crates of fish) in order to provide information about the lengths of a much bigger population of fish (the total catch of the fleet). The goal is that the characteristics of the sample should realistically reflect the characteristics of the total population. The problem issue is that the fish that are being measured range widely in size because a variety of different gears are being used, and no matter how big the sample size is, the variance in length measurements is unlikely to decrease much. To resolve the problem and reduce the variance it is necessary to stratify the sampling process so that samples are taken of similar fishing events. In other words, measure a sample of fish from the boats using gill nets or the catch that is made with gillnets, measure a sample of fish from the boats using handlines or the catch that is made with handlines, and measure a sample of fish from the boats using longlines or the catch that is made with longlines.



High variances may be also be caused by differences in geographical areas – the same species of fish might grow larger in one place than another. Temporal factors may also cause high variances. Wherever possible, sampling effort should be stratified so that samples are taken from similar fishing events or situations. In this way the variance of the variable being measured (whether it is total catch, species composition, length of fish or some other variable) will be reduced and it will be possible to discern real changes in the variable.

Data collection programmes also need to be designed to collect data as efficiently as possible and with this in mind there are other aspects of stratification that also need to be considered when designing a programme. These involve temporal and distribution stratification but prior knowledge of the fishery is required in these instances.

**Number of samples:** The issue that presents a major problem to most catch monitors and data collectors is the number of elements that need to be measured (the sample size) in order for the data to be useful. The answer is tied up with something called relative error. Most often no data are available and the likely safe sample size to achieve a pre-selected sample accuracy can be calculated from tables like the one below.

**Table 6:** Safe sample sizes at varying accuracy levels and target population sizes (de Graaf et al. 2015)

Accuracy (%)	90	91	92	93	94	95	96	97	98	99
<b>Total no. landings</b>	<b>Number of landings to be measured</b>									
300	29	35	43	54	69	90	120	163	218	274
400	30	36	44	56	73	97	133	188	267	356
500	30	37	45	58	75	102	143	208	308	432
600	30	37	46	59	77	106	150	223	343	505
700	31	37	47	60	79	108	156	236	373	574
800	31	38	47	60	80	110	160	246	400	640
900	31	38	47	61	81	112	164	255	424	703
1000	31	38	48	61	82	114	167	262	445	762
2000	32	39	49	63	85	120	182	302	572	1231
3000	32	39	49	64	86	123	188	318	632	1549
4000	32	39	49	64	87	124	191	327	667	1778
5000	32	39	50	64	87	125	192	332	690	1952

#### Activity 2.4

Small Group discussion, presentation and further discussion.

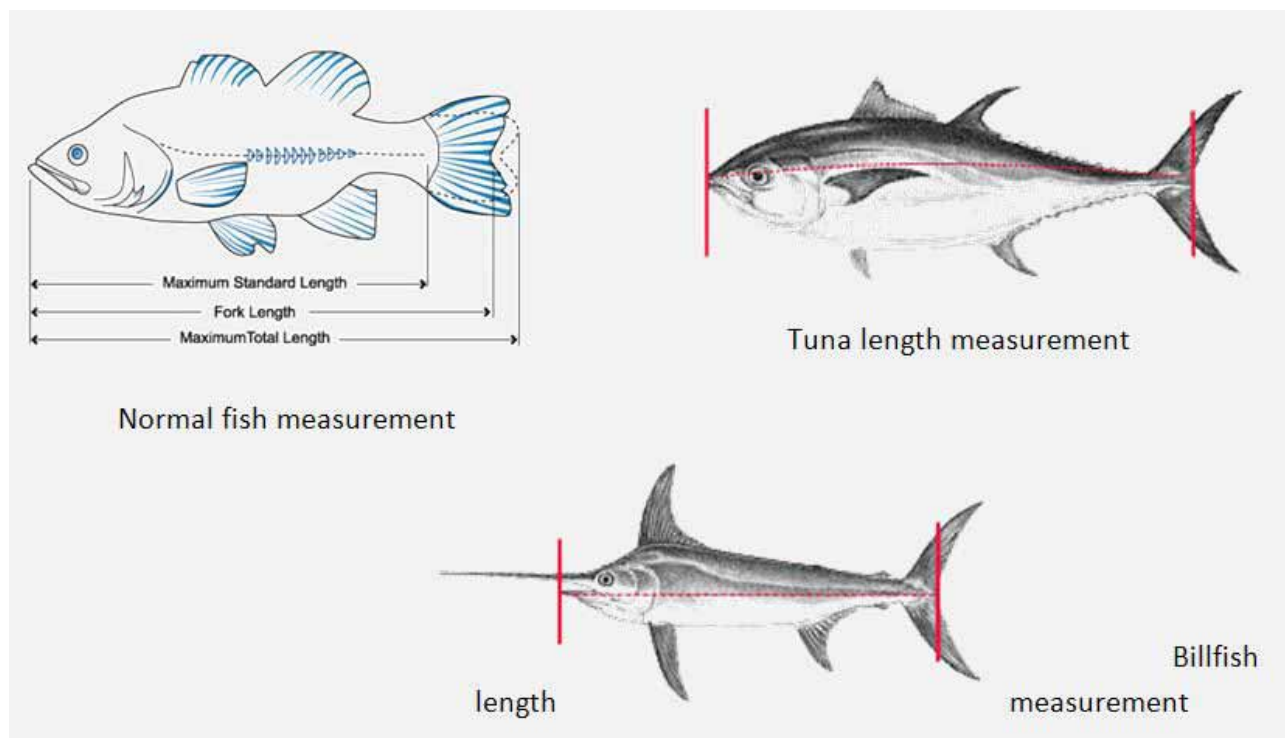
In groups prepare a brief presentation to the rest of the class where you address the following:

- Select one of the fisheries in your country. Provide details of its operational characteristics
- What data do you think you need to collect to manage this fishery
- Design a sampling programme and strategy to collect the data
- What indicators will these data inform
- Why are these indicators important for the management of your fishery?
- What are likely problems in the collection and interpretation of the data? How are these problems likely to affect the management of your fishery?
- How are you going to solve these problems?

**Size frequency:** In heavily exploited fisheries the mean size of the individuals in the fished population tends to decline and catch composition often changes. Length data are one of the biological parameters that are really important in the management of fish populations. Length data are relatively easily obtained using a fish measuring board and such data should be routinely collected (Figure xx) during catch sampling operations. Again, the issue of how many fish to measure can cause confusion. As outlined previously, the variance is the controlling factor and sampling should be stratified to reduce variance. In practice, except when sampling catches of small pelagic fish, the number of fish that are measured is very often determined by logistics.

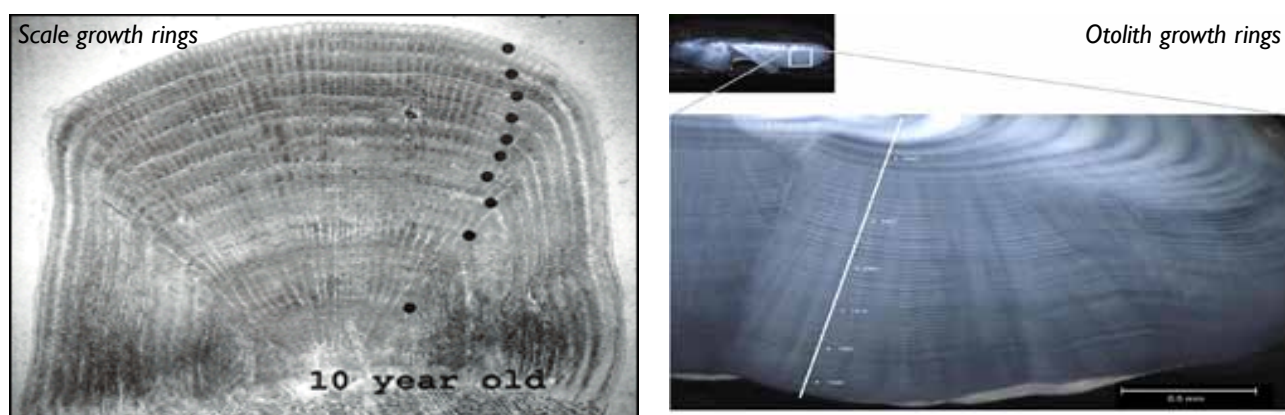
It must be noted that it is important to standardise fish length measurements. There are several ways of measuring fish length (Figure xx) – Standard or Pre-caudal length, fork length and total length are

the three measurements normally used. It is suggested that maximum total length (with the tail fin pressed into a straight line) be selected as the fish measure. Total length (the length from the tip of the mouth to the tip of the tail) is the measurement that most regulatory bodies work with when instituting size restrictions and it is the most easily understood measurement. Sharks with unequal size dorsal and ventral blades to the tail fin should be measured from the tip of the nose to the length of the longest tail fin element. Tuna are measured from the tip the mouth to the end of the centre of the tail while billfish are measured from the point of the lower jaw to the end of the centre of the tail.



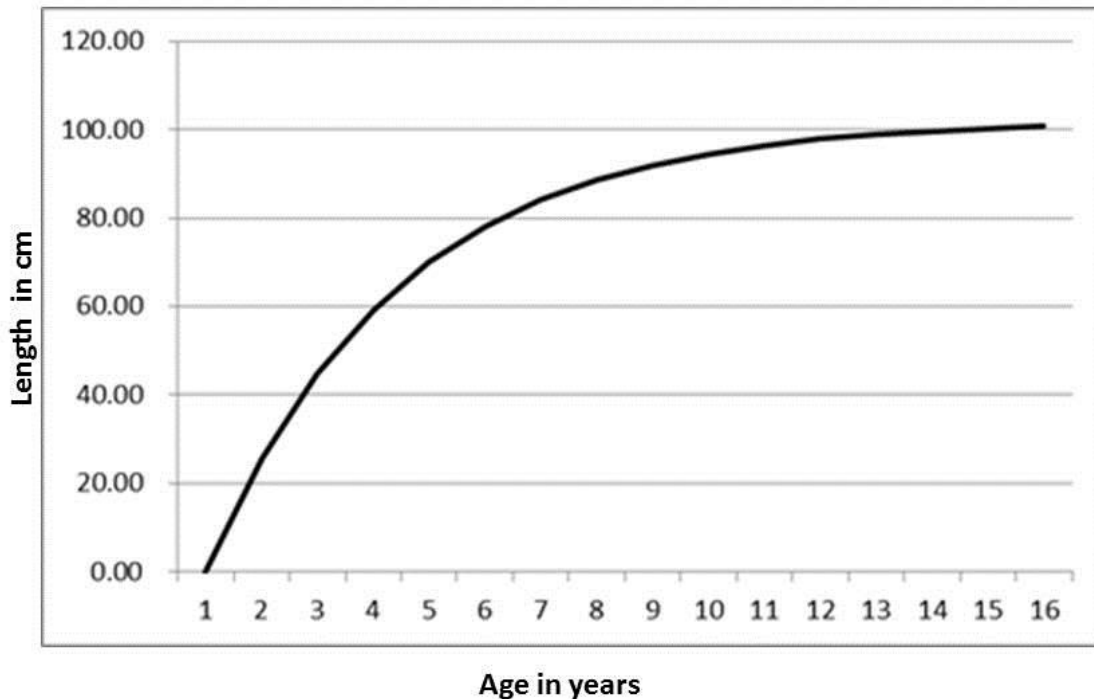
**Figure 23:** Length measurements for a) a typical fish, b) tuna and c) Billfish

**Age:** Length-Age keys or growth curves for different species of fish are an important component of fisheries modelling. Age data can be obtained by examining growth rings in otoliths (fish ear bones), vertebra and scales, undertaking tagging experiments, examining fin rays and even by examining length frequency distributions. Such investigations require a high level of skill and technical input. It should be noted that in tropical fish annual growth rings are either absent or formed irregularly and if present they are much more difficult to distinguish than in temperate species. This is probably the result of the lack of seasonal change in the environment in the tropics and the almost continuous spawning cycle of many tropical fish species.



**Figure 24:** Age data for fish can be collected by microscopic examination of annual growth rings on scales and otoliths

Age length relationships or growth curves are generally of the form shown in Figure 25. In many species of fish and crustacean the growth rates of males and females is different and must be determined independently.



**Figure 25:** A typical growth curve for fish or invertebrates

When collecting length data to use in age length keys it is critical to weigh the fish as well because some fisheries models use age-weight relationships. Crustaceans moult in order to grow. Thus at regular intervals the entire hard exoskeleton is discarded so there are no permanent hard parts from which age data can be extracted. The only way age data can be obtained for lobsters, crabs and other crustacean species is through tagging programmes and population size frequency measurements. Length measurements for lobsters and prawns generally involve measuring the length of the carapace (Figure 26) and for crabs the width of the widest part of the carapace is usually measured.



**Figure 26:** A spiny lobster and fish tagged with a spaghetti tag. For lobsters, carapace length is measured on the dorsal part of the carapace and sometimes includes the rostral horn (*Jasus* spp.) and sometimes excludes the rostral horns (*Panulirus* spp.)



**Weight and Length:** The relationship between length and weight (Figure 27) for different species of fish is an important component of fisheries modelling. To derive a length-weight relationship is quite simple but it is critical that the length measurement used is standardised as outlined above.

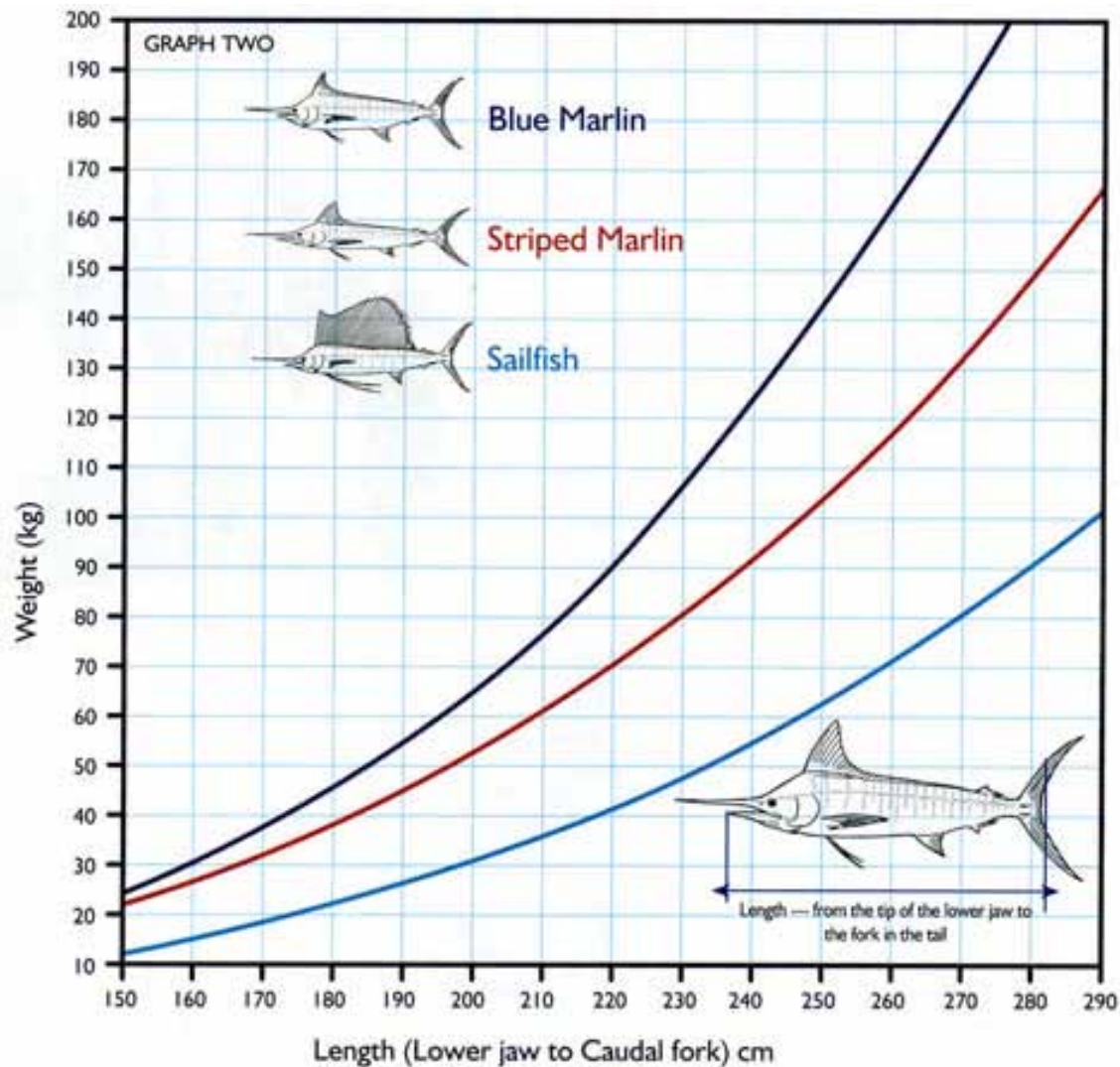


Figure 27: Length weight relationship for billfish species

**Sex and Maturity:** Determining the sex of fish is generally difficult without cutting the fish open and examining the gonads (Figure 28). Male gonads tend to be whitish and female gonads are yellow, orange, red or even purple in the case of some molluscs and echinoderms. In general fish, crustacean and mollusc gonads move through a number of stages from Immature – Maturing – Mature – Ripe and running – Spent – Resting.



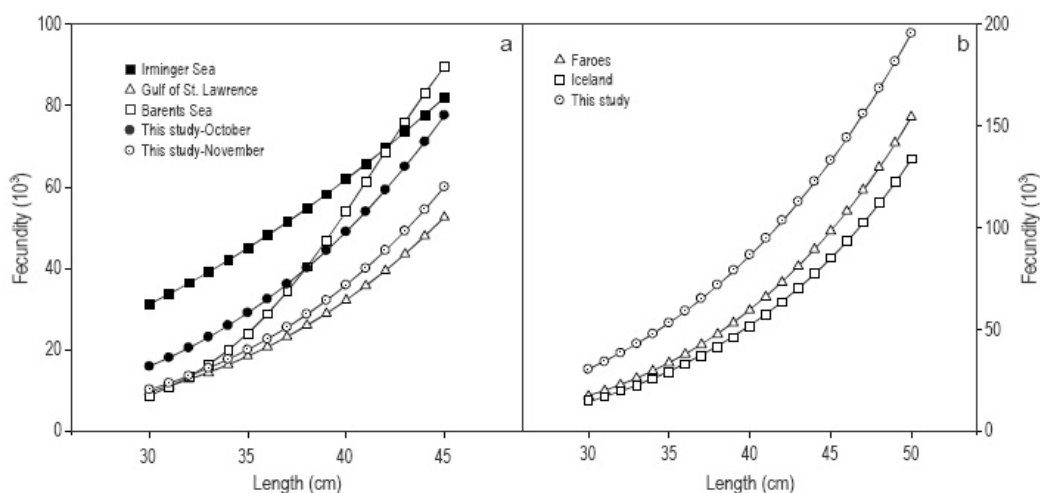


**Figure 28:** Ripe fish ovaries being removed from a sample

**Discussion:** Why would one want to determine the sex and maturity of fish?

These two parameters (sex and the age or size at maturity) are critical inputs into many fishery management models. For many linefish, crustacean and mollusc species, the minimum legal size (MLS) of capture is regulated by the size at which the animals reach maturity. The theory is that if MLS is set at size at maturity, then the organism has a chance to spawn at least once before it becomes available for capture. Age or length at maturity and fecundity are important inputs into management models because they are determinants of productivity.

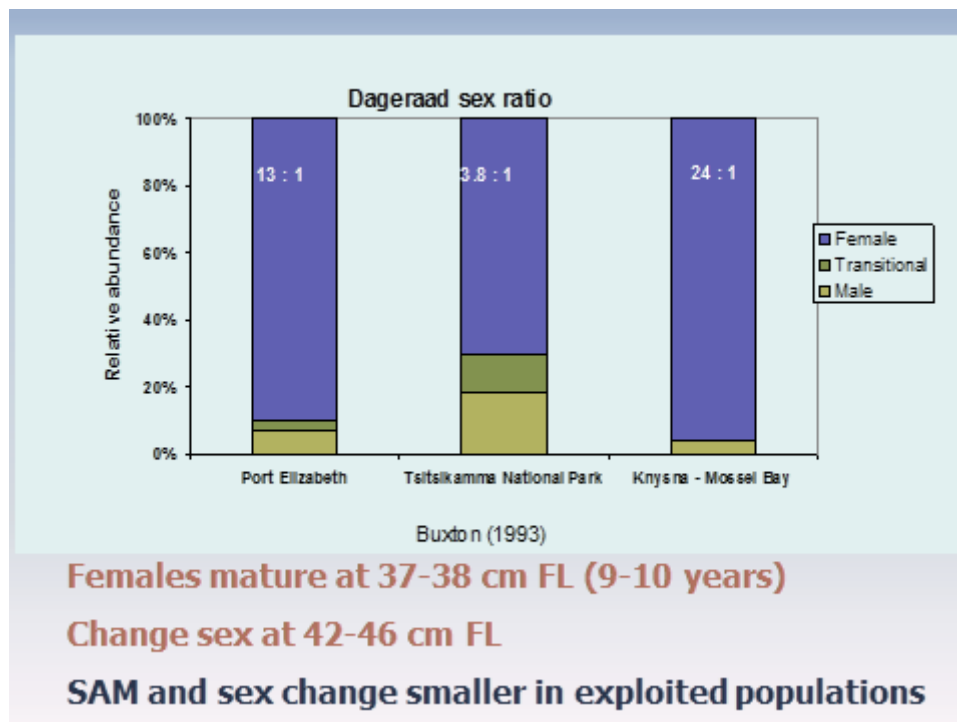
**Fecundity:** It is also important to note that fecundity in fish (the number of eggs that a female can produce) is not linearly related to size (Figure 29). One ten kilogram red snapper produces over twenty times more eggs at a single spawning than ten one kilogram snappers. Big fish also spawn more frequently than small fish. In addition, the eggs that large females produce have more yolk and the larvae have a better survival rate than the eggs and larvae produced by smaller females. Thus it is worth protecting large female fish particularly when trying to rebuild stocks.



**Figure 29:** Egg production in relation to size for deep-sea Red fish

**Sex change:** There numerous fish species (mainly Sparids and Serranids) that change sex as the fish grow larger and older. Fishing generally removes the large fish first and if a species changes sex as it gets larger severe imbalances in sex ratios can arise under heavy fishing pressure (Figure 30).

**Discussion:** Why would fish adopt sex change as a reproductive strategy?



**Figure 30:** Diagram illustrating the gross imbalances in sex ratios that can occur in fish species that change sex, when they are heavily fished (Port Elizabeth and Knysna-Mossel Bay). Fish in Tsitsikamma National Park are protected and sex ratios are 'normalised' for sex change fish.

### Activity 2.5

Small Group exercise, presentation and further discussion.

In groups undertake the following exercise:

- Measure and record the lengths of the sample of fish provided. Record the weight of each fish next to its length (weight is on the back of the fish)
- Calculate the mean length of the fish sample and the coefficient of variation
- Construct a size frequency histogram for the fish sample
- Develop a length weight relationship for the fish in the sample
- Calculate the sex ratio of the fish in your sample (gender is on the back of the fish)
- Develop a growth curve for the fish in your sample (age is on the back of the fish)

**Surveys:** Partly because of the potential for an unknown but important bias in the CPUE data, but for other reasons as well, responsible approaches to fisheries management also use a survey index of resource abundance. A survey involves the use of a research vessel to carry out a limited number of fishing events in a controlled manner. A fishing event may be a trawl, a purse seine set, a longline set, or a controlled trap fishing exercise. The essential decisions to be made for the design of such a survey are (a) how many fishing gear sets and (b) where and when to carry out the sets. The number of fishing gear sets will be constrained by cost considerations. For logistical and cost

reasons, a survey is limited in terms of the time frame over which it is implemented and this may have implications related to its effectiveness.

The design of the survey has to be carefully considered in order to provide as much unbiased data as possible.

Surveys involve the use of tens of trawls or trap lifts, while the commercial CPUE involves thousands or tens of thousands of trawls or trap lifts. Therefore statistical precision, or variance, is a major factor for surveys, and far less of a factor for the commercial CPUE where bias is a more important consideration (because commercial fishing effort deliberately targets high yield locations). Both of these indices play a role in management decisions, but the potential for reducing bias in the CPUE data and for minimising variance in the survey data is an active and ongoing topic in research supporting resource management.

#### **2.9.4. Economic data**

The aim of defining economic indicators is to assess the economic significance of fisheries to the national and local economies and assess performance of fisheries management in achieving economic objectives. Key macro-economic indicators include the gross value of production, the gross value added, the level of subsidies, the level of employment, the balance of trade and foreign exchange earnings.

Market prices are indicators of the demand for fish products. They indicate changes in markets and can guide future commercial fishing operations. Provided the factors influencing market prices are understood, they can guide fisheries policy development particularly with regard to management controls

The amount of investment in the fishing industry is one of the best indicators of changes in fishing and processing capacity in any country.

The number of people employed in fishing, processing and marketing can provide information on the importance of these sectors to the regional and national economy. This is important for policy decisions. Information can be obtained through surveys and sampling of the fishing, processing and marketing sectors (FAO 1999).

#### **2.9.5. Social and cultural data**

The significance of fisheries to the countries of the continent is great. This significance extends beyond the simple economic significance because fishing is a core component of the activities in which people engage in order to secure their livelihoods. Social and cultural data should be collected routinely with biological and economic information. Cultural and social features of the communities are major drivers of management strategies aimed at ensuring the livelihoods of coastal communities and sustainable resource use. The problem is that many of the indicators are not well defined.

The distribution of income is a measure of equity within fishing communities, and between fishing communities and the wider society. Sources of data are crew earnings, household earnings through fishing related activities, gender distribution through the entire fisheries related sector, and general

household data. Data can be obtained from industry records and by surveys and interviews (FAO 1999).

Distribution of fish consumption is a measure of food security and of social stability within fishing communities. This indicator enables policy makers to assess food security with respect to fish supply, not only of the nation as a whole, but also of vulnerable sub-groups such as mothers, children, the elderly and the poor.

The extent of fishing community involvement in fisheries management is an important governance indicator. Ecosystem approaches to fisheries management require the involvement of resource users in management decisions.

The demographics of the harvesting, processing and marketing sectors indicate community dependence on fisheries. These can provide important input into policy and management decisions related to fisheries and to other sectors of the economy.

#### **2.9.6. Enforcement and compliance**

Management strategies involve the formulation of management regulations and for the fishery to achieve its goals compliance with the regulations has to be achieved. The extent to which fishers and their fishing activities comply with regulations provides a valuable indication of the effectiveness of management measures. It is worthwhile for management agencies to collect data that inform compliance indicators because they provide a different perspective on the management of the fishery which can either reinforce or contradict other management views. In addition, lack of compliance with management laws and regulations may suggest that the policy or management decisions need to be reconsidered or adjusted.

The number and type of recorded offences is a first indication of the level of compliance. The results of judicial activities provide a further guide to the effectiveness of surveillance and enforcement measures. Thus, the number and types of warnings, prosecutions and convictions and the nature and scale of penalties should be recorded.

Increases or decreases in the level of conflict provide an indication of how good the management of the fishery is. Data are collected usually through conflict assessment reports which identifies the stakeholders, the time period, the intensity of the conflict the issue and the measures undertaken to resolve the conflict.

#### **2.9.7. Challenges in the fisheries data collection**

The sections above have outlined the kind of data that should be collected in order to manage fisheries and the ways in which such data should be collected. Detailed accounts of many of the problems associated with data collection have been highlighted in the relevant sections. The major problems all fall within the following areas.

- A lack of human and financial resources. This is probably the most critical constraint on data collection in AU countries.
- A lack of capacity/knowledge in fisheries monitoring at local level. We have indicated at several places in this manual that an understanding of the operational characteristics of the fishery for which data is being collected is absolutely critical to the design and implementation of a data

## Activity 2.6

Small Group discussion, presentation and further discussion.

In groups prepare a brief presentation to the rest of the class where you address the following:

- Describe two economic indicators that you think should be monitored for the main fisheries in your countries. Why are these indicators important?
- Describe how you would collect the data necessary to implement these indicators.
- Describe two social/cultural indicators that you think should be monitored for the main fisheries in your countries. Why are these indicators important?
- Describe how you would collect the data necessary to implement these indicators.
- Describe two enforcement or compliance indicators that you think should be monitored for the main fisheries in your countries. Why are these indicators important?
- Describe how you would collect the data necessary to implement these indicators.

collection plan. In addition data collectors need to understand the basic theory behind sampling and data capture.

- A lack of appropriate, cost-effective data collection systems. These need to be coordinated at a regional level so that everyone is collecting the same kinds of data.
- A lack of reliable, adequate and accurate information.
- Illegal gear and illegal, unlicensed and unreported fishing are cause for concern throughout the AU region. Such fishing activities have negative impacts on fish stocks and the environment. The impacts can skew the interpretation of data collected from legal fisheries.
- Data are sometimes not truthful.
- Recording errors creep into data capture either at initial recording or during transcribing.
- Weather conditions impact on data collection processes particularly in areas subject monsoon rains.
- Data collectors sometimes lack experience in the ways in which data should be recorded and what data to capture.
- Data capture staff may lack commitment to the process. It is difficult to always avoid this situation but adequate pay goes some way to maintaining commitment. It also helps considerably if monitors understand why it is necessary to collect data and what the consequences to fisheries might be if data are missing or falsified.
- Fishers and processors are often impatient with sampling and data collection processes and so data collection is compromised. The situation can be improved if they are made to understand why data collection is necessary.

General Discussion: What are the main data collection problems in AU countries:

- On the West African Coast
- On the North African Coast
- On the East African Coast
- On the South African Coast
- In freshwater fisheries in Africa

How do the problems differ throughout the region?



### 3. SYSTEMS AND TECHNIQUES USED TO MANAGE FISHERIES

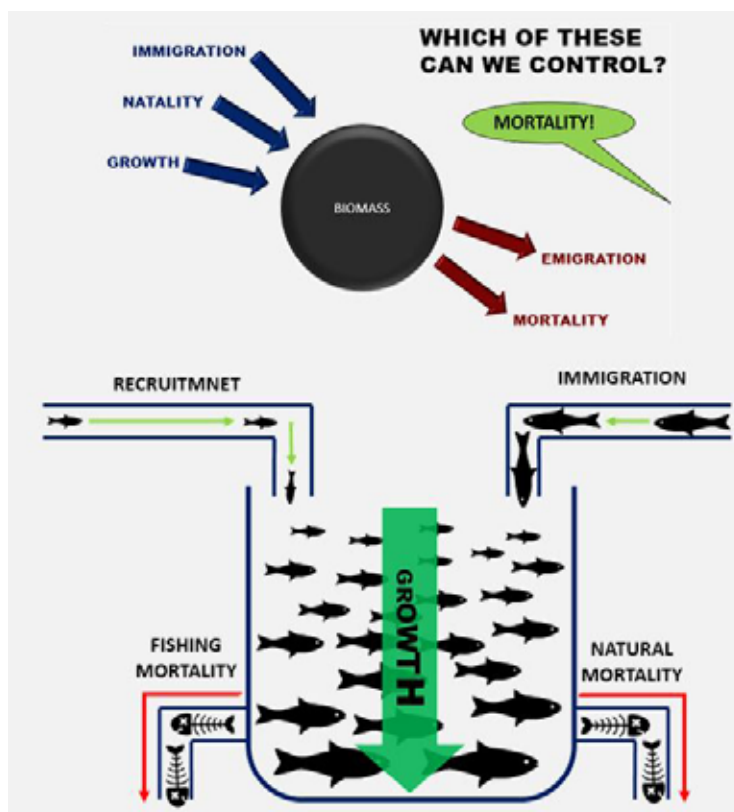
#### Activity 3.1

Small Group discussion, presentation and further discussion.

In groups prepare a brief presentation to the rest of the class where you address the following:

- Keeping in mind the earlier discussion of Sustainability, what do you understand by the term “Fisheries Management”?
- Describe the management arrangements of three fisheries with which you are familiar.
- What do you think is the most effective management measure for these fisheries?
- Why do you think it is the most effective?

Because of our high level of use of natural resources from the marine environment we need to manage the amount and /or way in which we capture these resources in order to achieve sustainable harvesting. It is important to understand that fisheries management involves a lot more than simply determining the Maximum Sustainable Yield or Maximum Economic Yield, or deciding on an F0.1 strategy (See **Appendix I** for a description of these terms). In the last couple of decades it has become clear that many marine species are harvested at unsustainable levels and that our use of fishery resources needs to be managed more effectively. The critical issue with all fisheries is that **YOU CANNOT TAKE OUT MORE FISH THAN RECRUIT BACK EVERY YEAR**. There are many factors that impact on fish recruitment rates over and above the size of the spawning population, and the reproductive dynamics of a fished population can get very complex, but at the end of the day, recruitment has to balance fishing and natural mortality otherwise the population will decline to a point where it is no longer a viable fishery either economically or as a source of food.



**Figure 31:** Simple representations of the factors that cause changes in the biomass of a fish population

### 3.1. METHODS USED TO DECIDE HOW MUCH CAN BE HARVESTED

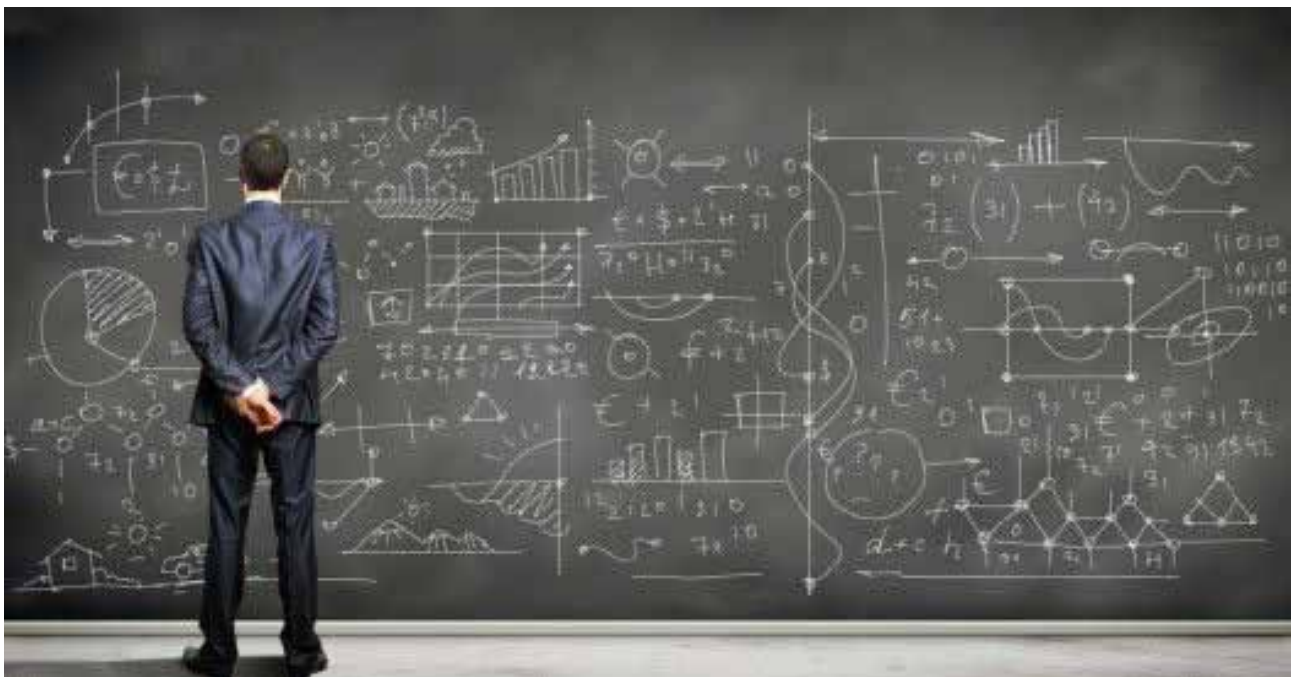
Stock assessment combined with modelling are the most commonly used tools to arrive at an estimate of the status of a resource and thus how much can be harvested on a sustainable basis. Stock Assessment involves estimating one or more of the following:

- size of the stock (how many individuals)
- age-structure of the stock (how many fish of different age and therefore the number of reproductively active individuals and potential reproductive output of the stock)
- actual reproductive output of the stock (estimating number of eggs and number of new recruits to the stock)
- mortality of the stock (natural mortality such as predation and fishing mortality - what proportion of the stock is caught)

Information needed for these estimations is gathered through a combination of techniques such as surveys, catch monitoring, biological sampling and abundance or stock size estimates.

#### 3.1.1. Modelling

Fisheries scientists then use the data to model populations and so reach an estimate of the number of fish that can be harvested from the stock. These models can be very sophisticated and may incorporate information about variable and size dependent natural and fishing mortality, variable environmental conditions and variable reproductive and recruitment success. Maximum Sustainable Yield (MSY), simply put, this is the calculated maximum number of fish (yield) that can be removed from a stock while allowing it to continue to produce the same yield for a particular time (usually long-term). Another is Maximum Economic Yield (the fishing level at which maximum profit is derived from a fishery – not always the same as the MSY).



**Figure 32:** Modern fisheries management involves complicated mathematical modelling

## **4. COMMON STOCK ASSESSMENT PROCEDURES AND THE DATA REQUIRED TO UNDERTAKE THEM**

The traditional ways in which fisheries were managed has changed drastically over the last hundred years or so. In the light of the current problems with fisheries management it is quite amazing that the famous naturalist Thomas Huxley (London Fisheries Exposition, 1883) suggested that marine resources were inexhaustible, and that all we should be concerned with is the development of the most efficient method of fishing.

Both scientists and fishers need to understand is that it is not possible to manage fisheries without some understanding of fisheries biology (scientists) and the numerical concepts relating to fisheries management (fishers). You will not be able to manage a fishery unless you understand basic fishery concepts that include both the numbers side of things and the fish side of things.

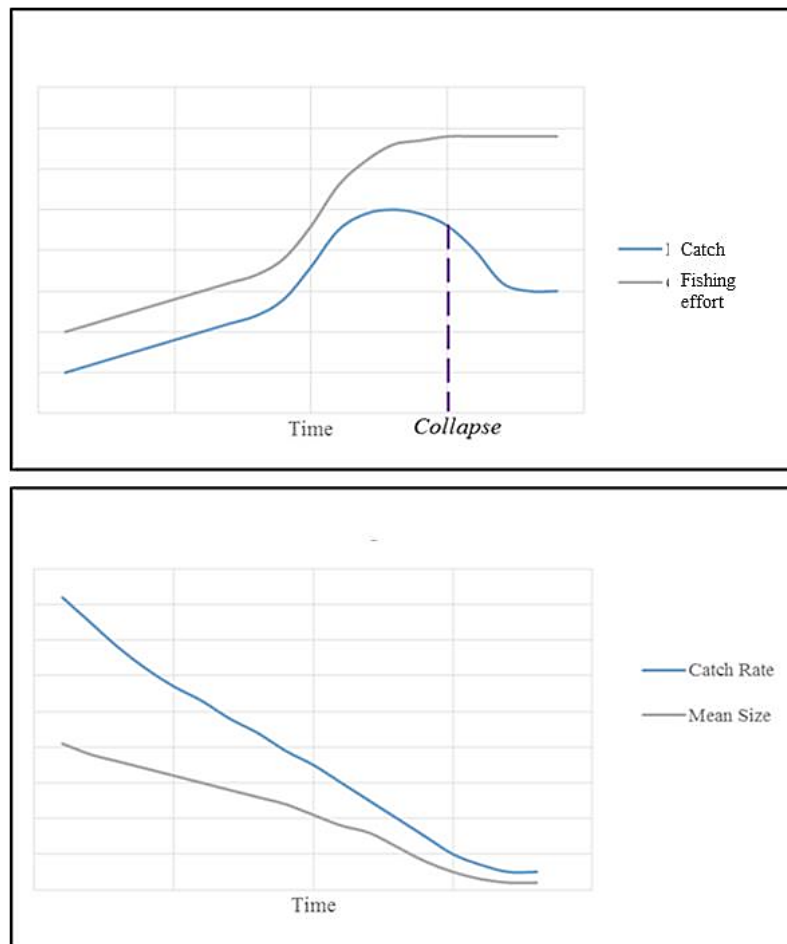
### **4.1. THE INEVITABLE AND THE PREVENTABLE IN MANAGED FISHERIES**

There will be few people that disagree with the statement that numerous fish resources around the world are badly depleted and generally provide fishers with very poor economic returns. The harvesting power of marine fisheries presently overrides any other natural factors and forces which shape and control fish populations. Uncontrolled fishing has the potential to drastically reduce the size of the exploitable biomass and radically alter marine ecosystems. Most of you have heard sad stories from people who complain that they used to be able to catch a bagful of fish every time they went fishing and now they catch nothing or alternatively they used to catch such big fish and now they only catch small fish. These stories may or may not be true but the reality is that it is simply not possible to exploit a pristine (untouched) fish resource and simultaneously maintain the original catch rates and fish sizes.

Typically what happens when fishing on a resource starts is that in the first year of fishing the resource is regarded as pristine, or very close to the size that it has been at for the previous thousand years. As fishing progresses, markets develop, and if the fishery is profitable there is strong incentive for new entrants to enter into the fishery. As a result more and more fishers enter the fishery and the manpower and number of vessels involved in fishing and in processing and marketing the landed catch increases. Consequently, the amount of fish landed each year increases, and the amount of money made increases, at least in the beginning (Figure 33). With experience, we know that the development path of new fisheries described above is never sustained indefinitely and eventually fisheries experience a number of logistical, biological and economic changes.

The first thing to happen is that the catch rate or CPUE decreases. This change over time in catch and fishing effort is described by Schaefer (1954) and Fox (1970). We discussed catch rate or CPUE in great detail earlier – CPUE is the number or weight of fish caught per unit of fishing effort.

The second thing to happen as a result of fishing on a fish population is that the average size of fish caught starts to decline (Figure 33). This is because fishing normally concentrates on larger fish, and because under any fishing regime fish have less chance of reaching a large size and old age because they are being caught by the fishing process. These two factors – lower CPUE and declines in mean size - start to have an effect on the profitability of the fishery - in most cases they cause a decline in profitability.



**Figure 33:** Typical trends in fishing effort, catch, catch rate and mean body size in a fishery, showing a development phase which culminates in a) maximum catch, followed by a collapse and then stabilisation at a lower level of catch and b) the mean decrease in mean size of fish resources over time

It is important to realise that the process we have described here is an unavoidable outcome of any new fishing operation. The question is not how to prevent it from happening but rather how far the process should be allowed to continue before the fishery becomes economically unproductive and/or the resource is under biological risk. Fisheries management is not about how to keep fish resources in their original state but rather about how far one should allow the resource to be depleted and what techniques and criteria should be applied to maintain it at an appropriate level.

In order to be able to put in place management to prevent this situation one needs to have a level of understanding of fish population dynamics, fish biology, how fishing affects natural processes and the extent to which a manager can change resource dynamics by managing the fishery.

To really understand the management of living marine resources we need to understand something about the biological concepts underlying marine resources.

#### 4.1.1. Mortality

All living organisms eventually die. The death of marine organisms is either a result of natural factors (seldom old age, but more commonly predation, disease, or injury) or of man induced factors (fishing mortality). The natural mortality of most marine organisms is very high when they are very young and vulnerable to predation. In fisheries management it is often assumed that natural mortality

is a constant proportion of the number of animals in the population, regardless of the size of the population. All mortality caused by fishing is classified as fishing mortality.

#### 4.1.2. Growth rate

Most fish species grow throughout their lifetime, although the rate of growth declines with age (Figure 25). The reduction of growth rate with age was first described by von Bertalanffy in 1938. Aside from age, other determinants of growth rate for fish include gender, locality, water temperature, food availability and sea conditions.

#### 4.1.3. Population biomass and carrying capacity

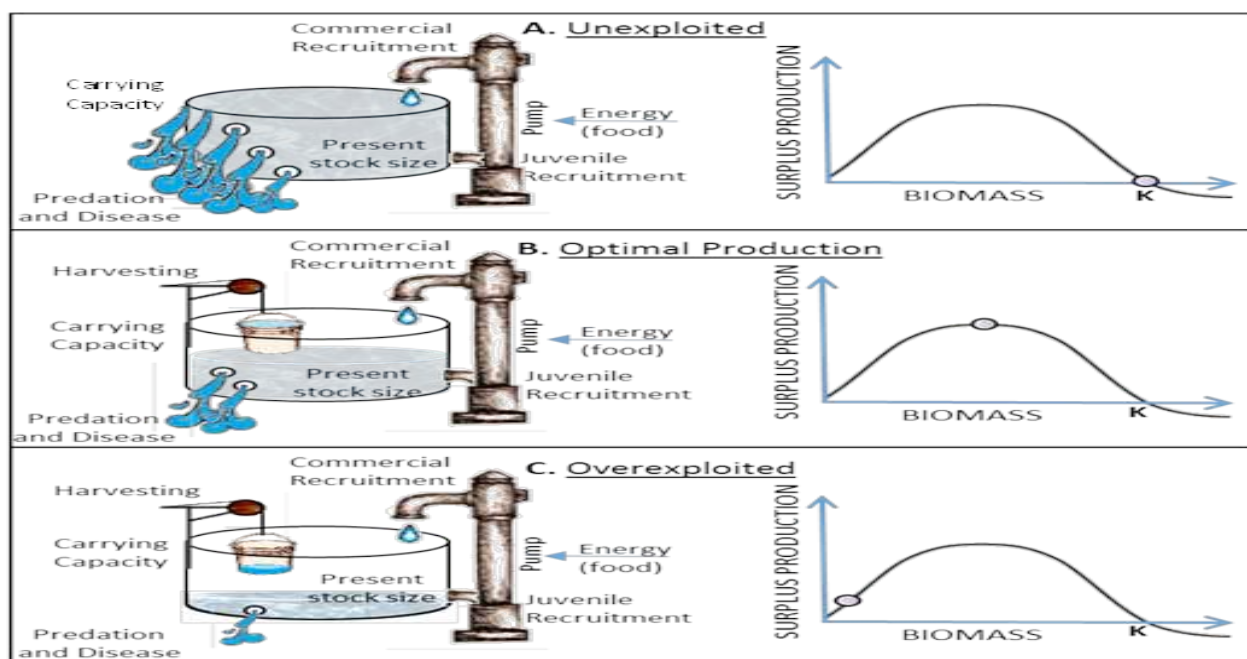
The size of a population can be expressed either in terms of the number of individuals or in terms of biomass. Biomass is the mass of all living individuals in a population. The population carrying capacity is the average size that an unexploited population reaches in its habitat under natural conditions. The carrying capacity is determined by a variety of biological and physical factors.

### 4.2. QUANTITATIVE CONCEPTS IN THE MANAGEMENT OF LIVING RENEWABLE RESOURCES

If we are going to manage our fish resources it is necessary to understand the basic quantitative concepts underpinning the practical management of living renewable resources. A proper understanding of these concepts is essential if one is to appreciate the basis for modern quantitative fisheries management.

#### 4.2.1. Carrying capacity

In modern fisheries science a key assumption underlying many management decisions is that an unexploited fish resource has a natural population size which is determined by the carrying capacity of the environment. The attached figure (Figure 34) shows three states of a fish resource: a pristine unexploited state, a state of maximum sustainable utilisation, and a severely overexploited condition.



**Figure 34:** Three dynamic states of a fish resource: A) - the pristine unexploited state, B) - the state of maximum sustainable utilisation, and C) - a severely overexploited condition. Dynamics are depicted either as water flows into and out of containers, or in terms of surplus production and population biomass on a graph on the right hand side.



**A: The pristine (or unexploited) state of the resource.** The water in the container represents the fish population. The maximum capacity of the container is equivalent to the population carrying capacity. Although the fish population may not be changing (i.e. the water level is not changing) there is a lot happening in the population. One can see that for the water level in the large container to remain constant, the amount of recruits must exactly balance the number of fish that are dying. At this stage no fishing is taking place.

**B: Maximum sustainable yield.** If the level of water in the container is reduced substantially, then the situation shown in part B of the diagram occurs. Now the number of fish dying naturally will be less, as represented by less water flowing through fewer holes. However, the number of recruits coming in at the top does not change. This is represented by the pump still working at full capacity. The amount of recruits entering the population is therefore larger than the amount of fish dying. Left to its own devices, the water level would increase back to its carrying capacity level. The only way to keep the water level at the same distance below its carrying capacity would be to remove the excess water from the recruitment stream using a bucket (i.e. harvest the excess production). This excess production is known as **sustainable yield**, and if it is not all removed, then the water level will increase. For this reason, the sustainable yield is also called the surplus production. For each resource there is some population size at which the surplus production/sustainable yield reaches a maximum value. This population size is called Biomass MSY and the corresponding maximum value of sustainable yield is known as the “**maximum sustainable yield**” and is abbreviated as **MSY**.

**C: Overexploitation:** Part C shows what happens if the water level in the large container is reduced too low. Now the inlet pipe of the pump is only partially submerged in water, and as a result the recruitment stream is reduced in size. Biologically, this means that the number of reproductive adults has been reduced below a critical level, and for the first time commercial recruitment has decreased. In this situation, the difference between the recruitment stream and the natural mortality streams gets smaller, and as a result the sustainable yield is substantially reduced. Even the removal of a small amount of water will stop the water level from rising.

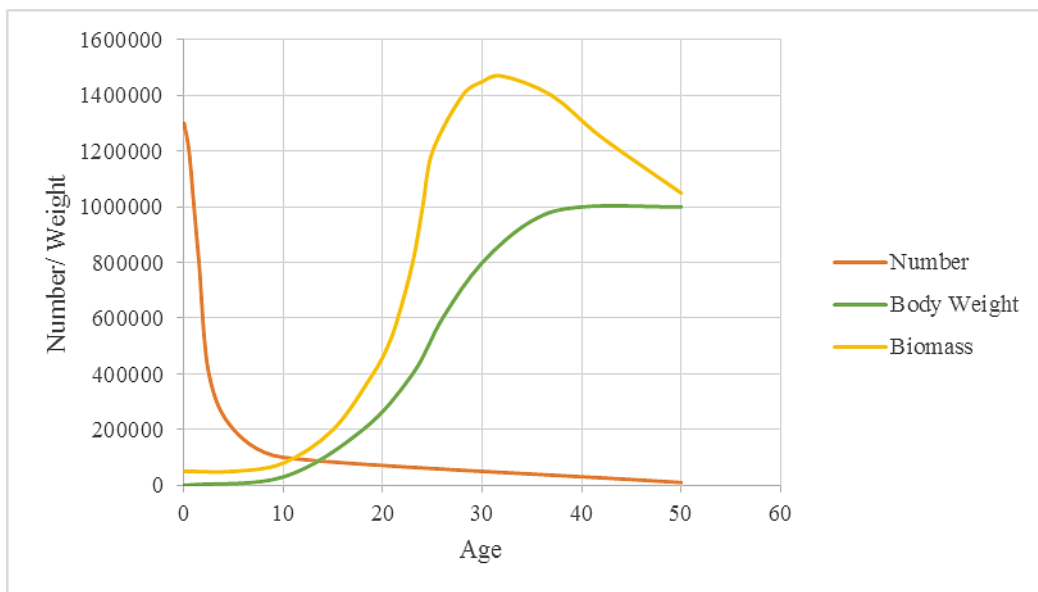
The x-y graphs on the right-hand side of the figure represent exactly the same process as described in the water analogy above except they are in terms of biomass and recruitment, and allow one to determine more precisely the population size which produces maximum sustainable yield, and the value of MSY.

It should be clear from this analogy that the largest catch experienced in the history of a fishery is not necessarily an indication of the MSY of the resource, and that in most cases MSY will be substantially smaller than the maximum catch experienced. The sustainable yield of a living marine resource is not determined solely by resource size. The ultimate sustainable yield would be the maximum net production in the resource, for a particular mix of size or age classes, and a particular sex ratio in the catch (if one sex grows faster than the other). This can get very complicated and is not something generally considered in estimates of MSY.

#### 4.2.2. Getting the most out of your fish

Fish populations are dynamic living entities. Fish are born, they grow, they reproduce and they die. The best age to harvest a cohort is when its biomass is at a maximum level. Figure 35 is a diagram of how the number of fish in a cohort declines as they age, and how individual fish might increase

in size as they age. By definition cohort biomass is the product of the number of fish multiplied by body weight, and this product normally shows a maximum cohort biomass at some intermediate age.



**Figure 35:** A representation of how the number of fish in a cohort decline as they age, and how individual fish might increase in size as they age. The third graph of this figure shows the product of the first two graphs, i.e. number of fish multiplied by body weight

Bio-economics is the discipline that combines concepts about the biological productivity of a resource with the economics of commercial fishing. The bio-economics of living renewable resources is the essence of fisheries science, and this is very different from simply the biology or the population dynamics of marine resources. When it comes down to the actual nuts and bolts of managing a fishery, the management problem is the trade-off of biological risk (the fish population must remain viable) against economic return. The overall aim is to ensure profitability for the fishery without compromising the long term productivity of the resource.

One must also keep in mind another feature of fish populations and that is that marine resources are inherently very variable and as a result they are not all equally productive. Different species have a very wide range of growth rates, natural mortality rates, fecundities and ages at which they start reproducing.

The manager needs to determine an appropriate target biomass that provides a sensible economic management framework which is compatible with the biological preservation of the stock. As with any other production operation, in order for fishing to be profitable, the value of the catch has to exceed the cost of fishing. Clearly, one should aim at a point at which the combination of resource productivity (sustainable yield) and cost of harvesting leads not to Maximum Sustainable Yield but rather to Maximum Economic Rent. Fisheries economists prefer to use the term “Economic Rent” to describe the difference between the value of the catch and the cost of fishing (see Section 4.2.4 and Figure 38 below). Economic rent is a term in economics which allows one to talk about the economic viability of an industry without using the word “profit”. Profit is a complex quantity calculated on the basis of a large number of variables for a variety of motives. From a fisheries management point of view one is really most interested in the value of the catch at its first point of sale, minus the variable costs incurred in landing this quantity of fish. This is at a level of fishing effort that is lower than the effort level at MSY and thus at biomass level which is somewhat larger than the biomass which generates MSY.

### 4.2.3. Fishing effort, sustainable yield and standing stock

Many fisheries around the world are fished at sustainable levels – the stock continues to provide the same catch year after year but for a variety of reasons they are fished nowhere near their maximum sustainable or maximum economic yields because the effort levels are too high and there are few options to change this situation. Many fisheries in the world are presently trapped in a high effort, low production fishing situation. Figure 36 is a diagram involving flows of water which attempts to demonstrate the relevant relationships. When very little fishing effort is applied over a very long time, then the resource eventually stabilises at a large population size generating a fairly small sustainable yield (A). There is some greater level of fishing effort which will result in the resource generating MSY (B). However, when the population size drops very low (C), it becomes much more difficult to harvest any yield at all. The effort levels are very high for a small yield which may well be sustainable but is nowhere near a maximum yield.

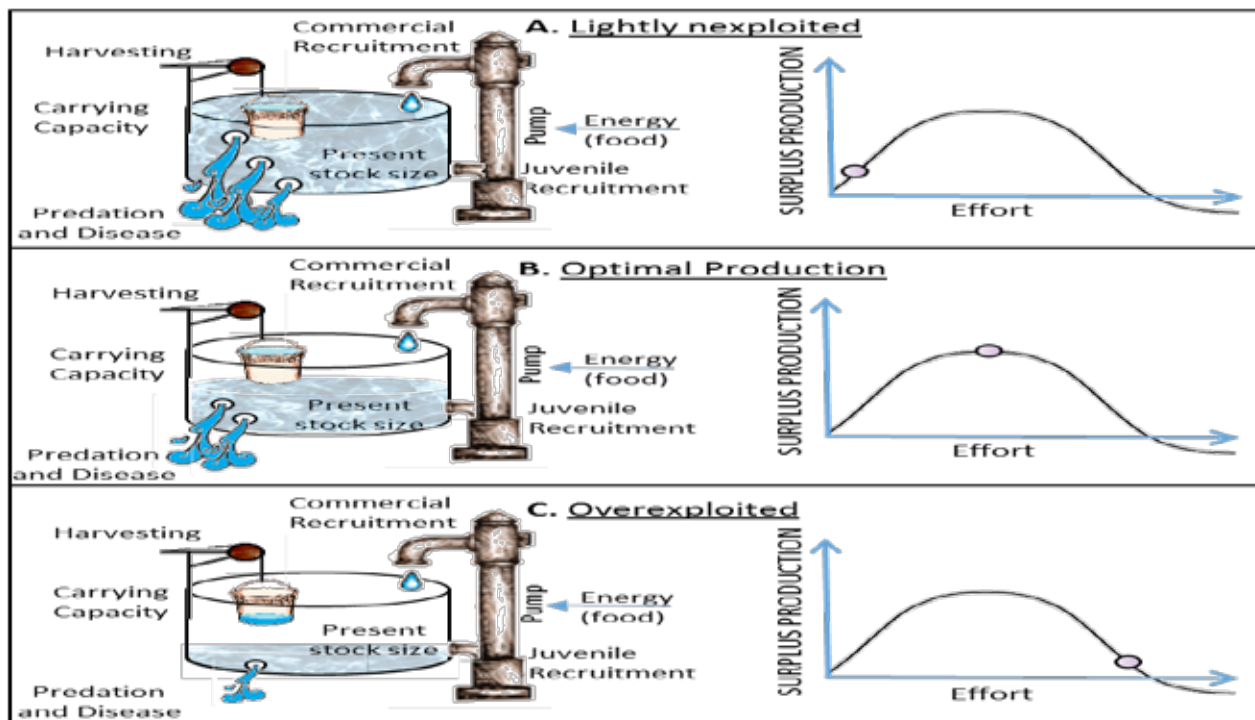


Figure 36: Three dynamic states of fish resources showing surplus production versus fishing effort

With reference to these concepts, two types of fish resources are generally recognised:

- i. **Productive fisheries:** These are fisheries where the recruitment and the natural mortality streams are quite large compared to the resource biomass. This leads to a curve of sustainable yield versus resource biomass that is quite distinctly humped, which means that the MSY is quite large compared to the carrying capacity.
- ii. **Unproductive fisheries:** These are those in which the recruitment and natural mortality streams are very small compared to the resource biomass. This leads to a much flatter relationship between sustainable yield and resource biomass.

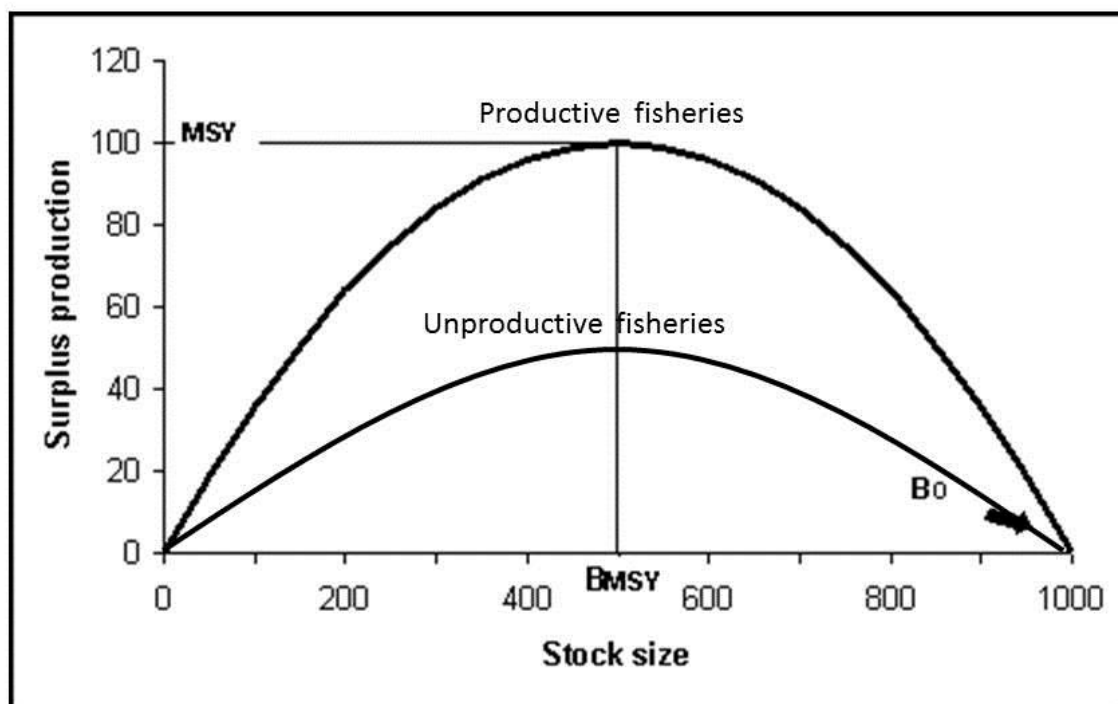


Figure 37: Graph illustrating stock size versus surplus production for both productive and unproductive fisheries

#### 4.2.4. Sustainable yield and profit margins

It should be clear from the previous section that sustainable fishing is not sufficient for a harvesting regime to be classified as biologically safe or responsible. Sustainable fishing also does not automatically make a fishery is productive or profitable. A very quick examination of the world’s fish stocks shows that most of them have been depleted well below their pristine levels and in the majority of cases the resource biomass is small. Even though the management regime may in theory provide sustainable catches, the fact that the biomass is so small means that productivity is much smaller than it could be. Figure 38 shows an x-y plot of harvesting cost and sustainable yield, expressed in common units, versus fishing effort. Because variable costs are proportional to fishing effort, the costs increase along a straight line as fishing effort increases. This figure also shows where the sustainable economic rent reaches its maximum value. The effort level which generates maximum sustainable economic rent is denoted MEY. The net economic yield is maximized at the level of effort at which there is the greatest difference between the sustainable yield curve and the fishing costs line. From

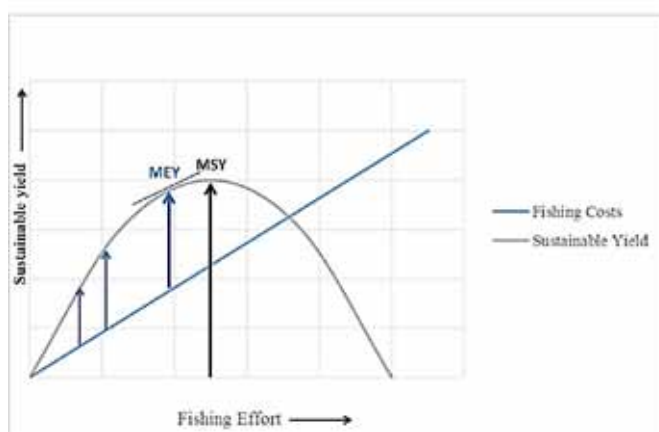


Figure 38: Plot of harvesting cost and sustainable yield, expressed in common units, versus fishing effort

Figure 38 it is clear that the effort level where the maximum sustainable economic rent is achieved is smaller than the effort level where maximum sustainable yield (MSY) occurs. In order to maximize the economic rent from the fishery it is necessary to keep the biomass of the resource at a particular point which is larger than the biomass which generates MSY.

It is important to appreciate that MSY is not necessarily the only goal for fisheries management. MEY is one other option and there are other sustainable yield levels for managing a fishery which takes into account a wide range of economic and social factors – for example the need to maintain high levels of employment may be the goal of managing the fishery and this may have an entirely different level of effort associated with it.

### 4.3. OVERFISHING

It is worth noting that there are no recorded cases of fishing leading to species extinction in marine fisheries. This is because it becomes too difficult and expensive to continue fishing long before a fish population faces any real prospect of extinction.

In an earlier section we discussed Growth over-fishing and Recruitment over-fishing. We need to now include the term Growth under-fishing. Growth under-fishing would occur if the size limit is set higher than the size at which the maximum cohort biomass is reached. Thus some catch potential is wasted because more fish have died from natural causes than is made up by the larger size that fish can reach before capture. Growth overfishing occurs when the fishery targets a size below the optimal size. In such a situation fish are removed from the sea before the cohort has had the opportunity to achieve its maximum biomass level. Calculation of the actual optimal size or age at which fish should be allowed to be caught is very complicated because fishing takes place over a range of cohorts and sizes. With regard to recruitment over-fishing it is necessary to distinguish between recruitment to the population as a whole (juvenile recruitment) and recruitment to the fishable stock (commercial recruitment). From a fisheries perspective, management is mainly interested in recruitment to the fishable stock rather than the number of post-larval fish in the ocean (See Appendix I). Most living marine resources are surprisingly resilient to severe declines in spawning biomass. It is well accepted that for many fisheries the spawning biomass can drop to as little as 20% of its pristine size without any measurable effect on commercial recruitment. However, if spawning biomass falls below 20% then widespread general experience with many different stocks indicates that commercial recruitment will probably be reduced. Below this critical spawning biomass level, recruitment overfishing has occurred – there are not enough spawning females left in the stock. A spawning biomass of somewhere between 20% and 40% is generally an ideal level.

When the size of a resource is reduced below the size which produces the maximum surplus production, then the resource is said to have been biologically overfished. When the size of a resource is reduced below the size which yields maximum economic rent (value of catch minus harvesting costs), then it has reached a state of economic overfishing.

#### 4.3.1. The simple and the complex

VPA and surplus production models are based on a fairly simplistic view of fish population dynamics. In reality the processes governing fish population size are much more complex



Nowadays, the availability of very powerful computers has made it possible to explore the use of more sophisticated techniques which can combine the logic of the VPA technique with the surplus production modelling approach, and go even further to incorporate additional complexity. These models comprise the set of age-structured production models and size-based modelling approaches. These models try to represent the full complexity of growth, death, fishing and reproductive processes in a population on the computer, and then use techniques to estimate the various important quantities governing the changes in population size over time. The models can then be run forward in time to try to understand the implications of different future harvesting strategies for the resource. The models are able to make use of a much wider variety of data about fisheries and fish stocks than was previously possible. They also involve estimating a much larger number of important quantities than was previously considered advisable or even feasible. Ever more sophisticated computer hardware and software has made this new approach increasingly accessible to fisheries scientists and have allowed scientists to eliminate some of the biases commonly found in fisheries data and particularly CPUE data. However, these techniques are not the subject of this training manual.

It must also be noted that complex models are open to abuse. One problem is that the models produce results even when there are very few data available on the fishery. Scientists and others involved in the decision making process are seduced by the realism of the numbers that are being produced, or by seeing similar numbers produced over and over again, year after year. Some people refer to this phenomenon as hyper-rationality, one in which the numbers appear to be rational, but in reality they have no firm basis in fact. The ease with which these models can be run on modern computers to produce what seem to be seemingly realistic results puts a burden on scientists to properly test the models to verify that their results are robust and useful.

#### **4.4. MANAGING FISHERIES**

Having covered all this detail on the how, why, where and when of data collection and its input into various fisheries management models we need to ask ourselves if we are any wiser with regard to managing the fisheries for which we are responsible. We need to go back to basics and remind ourselves what the stock assessments give us. They give us an estimate of the productivity of the resource, how this productivity is related to the resource at different biomass levels, and, critically, an estimate of the present resource biomass level. However, mathematical models do not and in fact cannot provide an answer to the basic management questions: “What is the best way to manage the resource? What is the optimal management approach?” It is generally accepted that the management process cannot be purely scientific or purely mathematical because of all the social, economic, political and cultural issues typically associated with fishing. There must be an overall objective which the management can practically implement.

The first step in the management process is to identify the objective of resource management for the resource under consideration. From a biological point of view the main issue is the size of the resource biomass. Is it too low, too high or adequate? The answer to this question is a critical management driver. From an economic point of view there are multiple issues that management might need to address such as the best market price, catch stability priorities, rights issues, processing issues etc. From a social or cultural point of view the main issue is generally one of livelihoods – fishing is a core component of communities’ livelihoods and cultural traditions. Stability is an important economic, social and cultural objective in resource management but the difficult question to answer is which of the priorities or what combination of priorities should guide the management of the fishery.

Once an overall objective or set of objectives has been identified for a fishery, the next step is to devise a harvesting strategy which is able, at least in concept, to achieve the stated objectives. However, whatever harvesting strategy is proposed, it is of no use unless adequate management controls are in place to implement the strategy. An important component of any fisheries management system is therefore to ascertain for a given fishery what kinds of management measures are practical and useful?

#### **4.5. METHODS OF FISHERIES MANAGEMENT**

Fisheries management has now progressed to include a science that uses sophisticated technology and theory to predict how many fish should be caught, who should be allowed to catch them and when and if they should be caught.

##### **4.5.1. Modern Fisheries Management**

Marine fisheries are probably the most challenging and difficult of all natural resources to manage effectively. Management measures can be divided into two kinds: input controls and output controls. The simplest definition of input controls is those that are concerned with fishing effort and whatever goes with it (fish gear). Output controls involve the catch itself and the size mix of the catch. Under the heading of input controls is included the following:

##### **4.5.2. Input controls**

Input controls generally involve limiting the effort or the amount of fishing permitted for a particular fishery, thus indirectly limiting the amount of fish that can be caught. Input controls may take the form of:

- Gear restrictions (only certain types of nets allowed, regulations on mesh size or net length, maximum boat or engine size, i.e. limiting the capacity for an individual to fish)
- Number of entrants to the fishery (number of permits available, maximum number of crew members)
- Time when fishing is allowed (closed seasons or maximum 'time at sea', number of days an operator is allowed to fish)
- • Restrictions on where fishing is permitted (closed areas, territorial waters, marine reserves)
- Input controls are used for smaller more complex fisheries, typically artisanal, recreational and subsistence fisheries.

##### **4.5.3. Output Controls**

Output controls limit the amount of fish that can be harvested and are used mainly for big industrial fisheries. Limits usually take the form of an industry Total Allowable Catch (TAC) or an individual quota whereby the number or weight of fish (of a single species /stock or group of species) that can be captured by a person (or company) with a right to fish for that species is set. TACs are usually set through a combination of scientific research and recommendations, and discussion between the regulatory fishing authority and fishers. Other output controls are maximum or minimum size limits and prohibitions on the capture of vulnerable biological stages such as egg bearing or soft shell crabs and lobsters.

In recreational fisheries, output controls would take the form of bag limits and minimum legal sizes but controls are mainly of the input type – gear, spatial and temporal restrictions and permits.

Modern fisheries management makes use of fisheries science (biological research, including stock assessment, and modelling) to recommend allowable catches and regulations. Other features of modern fisheries management are social aspects (consultation with user groups, allocation of fishing rights), enforcement (permitting, inspection of catches, anti-poaching, prosecution of offenders) and education (education of fishers and the public about fishery issues and regulations).

#### **4.6. OPERATIONAL MANAGEMENT PLANS (OMPS)**

An OMP or Operational Management Plan is a relatively simple formula or model which is self-correcting because the Total Allowable Catch (see Section 4.5.3 above) is adjusted in response to changes in resource indices such as CPUE or mean size so as to keep the resource biomass on a desired trajectory. Relevant examples of resource indices include: commercial catch rates, survey biomass estimates, catch age or size structure data, tagging data and catch sex ratios. OMPs are the latest scientific effort to deal with human imperfection in estimating resource status and the natural volatility of biological and ecological systems. Although the OMP often consists of a relatively simple formula, the rationale behind its development is both conceptually and computationally complicated.

OMPs basically consist of a set of clearly defined decision rules specifying:

- exactly how the regulatory mechanism (e.g. a TAC) is to be set
- what data are to be collected to set the TAC
- exactly how this data is to be analysed to set the TAC

Management parties agree upon the rules to be applied to the resource model. Once the decision rules are agreed upon, this management procedure is then implemented for a number of years. After this time the procedure is reviewed and modified if necessary. OMPs help to simplify management, as the rules are agreed upon at the outset, and these stand for a number of years, so there should be no conflict as to how management implements its decisions. They are particularly useful when there is potential for political interference in managing a fishery. However, the effectiveness of OMPs as fisheries management options has not really been tested internationally.

##### **4.6.1. Alternative Management Approaches**

Output controls (usually in the form of TACs and quotas) have in recent times been the most commonly practised methods in industrial fisheries management. In many fisheries they have proved unsuccessful and globally most important fisheries are considered to be over-exploited. The reasons are many and varied – discarding of bycatch, political meddling in TAC determinations, lack of reliable biological and catch data for models, inaccurate and inflexible models, under-reporting on the part of fishermen and inspectors and illegal, unreported and unregulated fishing. There is thus a growing realization that other techniques are needed for the management of many fisheries.

An approach that is rapidly gaining traction among fisheries management authorities is the Ecosystem Approach to Fisheries Management (EAF). Fishing cannot be conducted without some form of ecosystem impact, at the very least on the population structure of the species being fished. However, many fisheries also have impacts on ecologically associated species, whether they be predators or prey of the fished species, competitors for ecological resources, or species that also occur in the area being fished and are impacted by being incidentally caught (by-catch) or have their normal behaviour disrupted by fishing activities. Many fisheries also have serious physical impacts on the habitat where they fish, particularly through gear such as bottom trawls and they have impacts on the

communities who undertake the fishing process. The EAF approach is still in its infancy but merits serious consideration because it is becoming very clear that it is impossible to manage fisheries based purely on knowledge of the characteristics of the targeted species (viewed in isolation from its place in the ecosystem). EAF essentially reverses the order of management priorities so that management starts with the ecosystem rather than a target species. EAF aims to sustain healthy marine ecosystems and the fisheries they support (Figure 39).



**Figure 39:** Taking into account the whole ecosystem can make fisheries management complicated

Area-based fishing rights, generally known as Territorial User Rights Fisheries (TURF), is an approach to the management of fisheries in which exclusive rights are assigned to individuals or groups to fish in certain locations. Well-designed TURFs place controls on fishing mortality and hold fishermen accountable to comply with these controls and manage the resource. TURFs are usually allocated to and managed by organized groups of fishermen rather than individual fishers. Most TURF systems do not grant ownership of fishing areas but instead they allocate exclusive harvesting rights for one or more marine species in a specified area. Clearly they work well for species like abalone that will not move beyond TURF boundaries but are less suitable for mobile species that are likely to move beyond the area boundaries. However, they can be designed for more mobile species as well. Well-designed networks of TURFs can be used to manage more complex fisheries, including those with mobile species and multiple groups of fishermen.

Examples of TURFs are widespread – some examples include lagoon fisheries in the Ivory Coast, beach seine net fisheries along the West African coast, collection of shellfish and seaweed on a coastal village basis in South Korea and Japan, and controls over outsiders by fishing communities in Sri Lanka. TURFs have a particularly long history in traditional, small-scale/artisanal and indigenous fisheries. Benefits of TURF management systems include:

- Improved management at a fine scale. Local science and community participation in TURF management allow for locally-appropriate decision making.
- Direct benefits to habitat conservation. By allocating a specific marine area, TURFs encourage conservation of fish stocks and the marine ecosystem. Fishermen are rewarded for protecting habitats and fishing responsibly.
- Direct benefit to small, local fishery-dependent communities. TURFs can increase the income of artisanal fishermen and support food security for the communities that rely on the resource.

The overriding advantage of TURF systems is the principal that there is local solution of usage issues. ITQs or Individually Transferable Quotas is catch share system, which can be used by regulatory

authorities to manage fisheries. ITQs are designed to give their owners exclusive and transferable rights to a given portion of the TAC of fish. Authorities establish a TAC for a given species and then divide this total among the individual fishers or firms in the form of individual catch quotas, usually as a percentage of the TAC. These ITQs are transferable through selling and buying in an open market. Allocation, transfer and definitions of ownership of quota can be enormously simplified under the proportional ITQ system. In theory ITQs remove the race to catch as much as possible as fast as possible and create an incentive among fishers to regard the fishery resources as assets that promise to deliver a stream of economic benefits over the long term. However, ITQs have been the subject of much discussion recently. An ITQ actually promotes economic efficiency, rather than conservation or equity, and effective fisheries management is not about economic efficiency alone. It is also about conserving the resources, preserving the ecosystems that support the resources through time, and ensuring equity and social justice in the use of these resources.

#### **4.7. CONCLUDING REMARKS**

There is a common perception that managing fisheries is all about being able to undertake quantitative analyses of fish stocks and then make rules about amount of fish that can be caught and the number of fishers that can be allowed. However, there are actually four general areas of resource management and these are the harvesting strategy, the policy on access rights, the control measures, and enforcement of all rules and regulations. All of these must be jointly implemented to achieve maximum benefit from a resource. The management of the fishery will only be as strong as the weakest link in the management structure. This is as true for enforcement as it is for any of the other three areas of management. It is no use having the most scientifically acceptable harvesting strategy in the world, if there are insufficient personnel available to enforce the necessary control measures. It is a good idea to keep regulations simple, effective and enforceable. Regulations which are too complex to be sensibly interpreted serve no useful purpose, and will be contravened.

There is a common misconception amongst management authorities that they cannot and should not make management decisions when data, and scientific knowledge, are lacking. The fact is that there will never be a time when a management authority or anyone else will have complete knowledge of all biological, ecological, physical, environmental and other data relevant to the management of fish resources – so this is not a realistic expectation. Scientists and managers must use whatever data they have to assess the state of the stock and its productivity.

The critical factors that determine the kind of controls that should be implemented in a fishery are:

1. The number of participants,
2. The number of access points to and from the resource (i.e. landing sites)
3. The mobility of the species (e.g. bottom dwelling immobile like perlemoen, or surface dwelling and mobile like yellow-tail)
4. Ability to quantify the catch
5. Ability to quantify fishing effort, and its relationship to resource biomass and catch
6. The degree of bureaucratic power for top-down imposition of controls
7. The existence of a recreational fishery alongside the commercial fishery, in which the recreational component is run on an open access basis.

When considering the development of fishing controls, management authorities should keep these factors in mind.

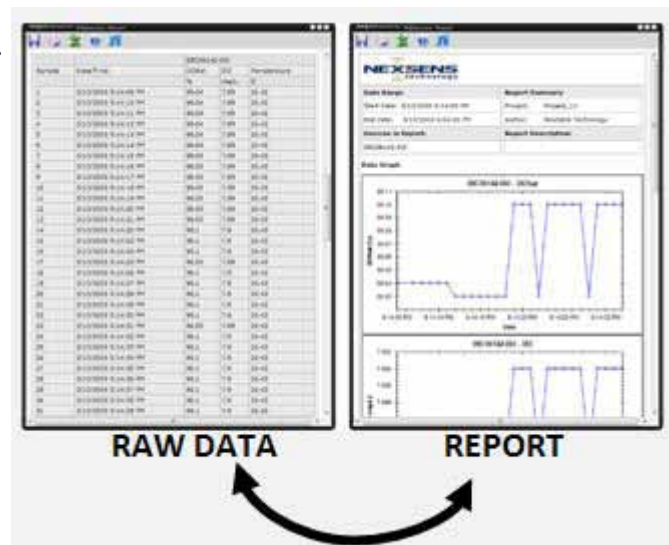


## 5. HOW SHOULD THE DATA BE MANAGED?

Data are collected in order to manage fisheries effectively. The most important elements of data management are i) the storage of data in raw primary form (i.e. not aggregated, filtered or transformed in any way) and ii) the security of the data. There are countless cases on record where an existing or previously accepted analysis has to be reviewed or revised and it cannot be done because the raw data no longer exist or they have been transformed to a point where the problem issue cannot be inspected. Effective data management needs to insure authorities and fisheries scientists are always able go back to the raw data.

Technological advances have provided powerful platforms for data collection and management, making the ongoing costs of these tools relatively cheap. Fisheries managers should opt to make use of these helpful packages as they have a myriad of advantages over traditional data collection tools.

Today data should all be stored electronically in a secure, electronic-friendly environment and all electronically stored data should have at least one **backup** that is refreshed at a minimum of **once a week**. Ideally the system should back itself up **every day**, removing the need for human input. If fisheries managers in the AU are to integrate their historic data collection, analyses and management systems with these technologies, then suitable software programmes that can integrate with each other needs to be selected. Fisheries managers also need to be aware that customised databases



often rely on the continued involvement of the system developers and for a variety of reasons this can become a problem issue. On the other hand, commercial desktop database software may also have limitations, most often associated with the programmes' ability to store and process very large quantities of data. It is a critical issue that data storage and processing facilities in different AU countries should be able to relate with each other to integrate the management of shared resources. In this respect there are advantages to the use of commercially available software.

The suitability of software and database design should be defined by a number of parameters including user friendliness and ease of operation, the ability to store original raw data, flexibility, data input validation controls, the ability to integrate data collection and data analysis, preferably by way of embedded functions and reporting procedures, data import facilities that allow the incorporation of data stored in different formats like spreadsheets or word processors, and the export of data into different formats.

Long-term use of a database requires a commitment to support the data management application. Adequate personnel should be available not only for routine operation, but also to modify the system as the need arises. It is also important that the security of, and right of access to, the information stored in a database is clearly defined right from the start of the database development.

Finally it is worth taking note of the following two statements from the FAO Technical Guidelines for Responsible Fisheries (1997).

**“The collection of data is not an end in itself, but is essential for informed decision-making.”**

**“States should ensure that timely, complete and reliable statistics on catch and fishing effort are collected and maintained in accordance with applicable international standards and practices and in sufficient detail to allow sound statistical analysis. Such data should be updated regularly and verified through an appropriate system”**

### **5.1. WHAT IS A DATABASE?**

A database is used to store the “raw data” ensuring the raw data can always be accessed by fisheries authorities. Data entered into the database should therefore be void of any pre-processing. For example, the catch data to be entered in the database are exactly the same values as those written in the catch forms by the skipper/observer. All processing of data should be executed by the database system. If processed data are entered, the tracing of errors (validation of data) becomes difficult if not impossible. In addition, re-analysis of pre-processed data may be impossible.

It is important to develop the database simultaneously with the development of the data collection programme, as the database acts as a check on the consistency of the data collection programme and both inform the other. The database will show if the programme actually produces the expected output.

A “database” consists of “Tables”, “Forms” and “Reports”. These three main components are linked by aid of “Relations” and “Queries”. Unlike a flat spreadsheet a database is a dynamic means of storing and accessing data in a way that simple for the user and limits loss of data.

Below is a brief outline of the basic concepts and terms commonly used when discussion databases. We are not going to go into great detail in how to design a database however it is important to have a broad understanding of the terms commonly used and the many “relationships” that can be created between the tables in a database.

### **5.2. TABLES, RELATIONS AND QUERIES**

#### **5.2.1. Tables:**

- Tables contain the data in the database.
- A database is made up of many tables.
- Tables are made up of “rows” and “columns”.
- “Rows” are individual records.
- “Columns” are specific fields.
- Fields in tables are either “Key - fields” or “non-key-fields”
- “Key-fields” are aid in identifying the record and are the fields that used when linking records from one table to another using “relationships” (relationships with be discussed in later on).
- “non-key-fields” are fields that contain relevant data.

	Primary Key	Foreign Key Field <i>(Primary keys from other tables)</i>	Non-Key-Field <i>(Values)</i>
Records	VesselID	TripID	LandedLiveCatchWeight
	SA123	123-04-16	300
	AG578	578-03-16	200
	MZ543	543-02-16	400

**Figure 40:** An example of database table with Records, Primary Key, Foreign Key Field and Non-Key-Fields labelled. The Primary Key is the key that identifies each record in the current table, The Foreign key links the current record with the record identified by the primary key from another table and non-key-fields are the fields where values are entered into the database.

### 5.2.2. Forms:

- Forms are the tools used to interact with the database.
- They act as the user interface and prevent users interacting directly with the data tables.
- This makes the entering of data more user friendly, limiting data entry errors and preventing historic data from being altered.

Fishing Gear

**Fishing Method**  
Trawl ▼

**Paired/Single**  
Single ▼

**Mesh Shape**  
Square ▼

**Codend Mesh Size**  
80 ▼

**Warp Cable distance**  
10m

**Trawl Type**  
Bottom ▼

**Trawl Door Distance**  
10m

**Bycatch Excluder (Y/N)**  
Y ▼

**Data field where pre-loaded categories can be selected from**

**Data field that values can be entered in directly**

**Figure 41:** An example of a hypothetical form that fishers are able to fill in with the relevant information

### 5.2.3. Reports:

- These are reports that can be produced by the database software.
- They can be designed to produce specific outputs relevant to fisheries management.
- This can include: resource evaluation, CPUE analysis, stock assessment, bio-economics etc.

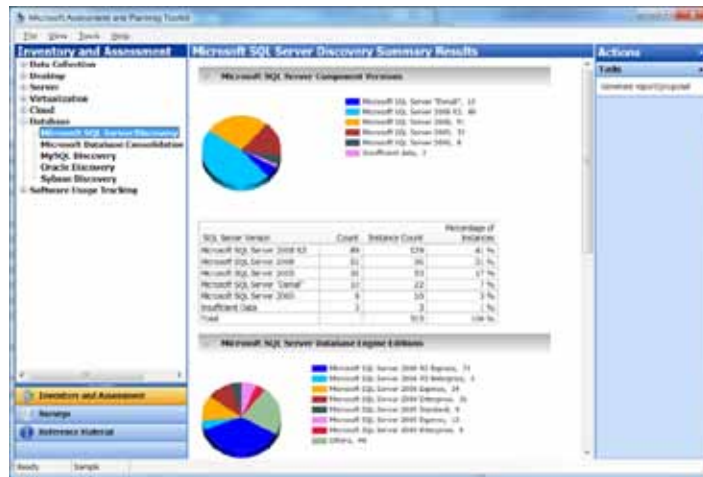


Figure 42: Example of report produced by a database software system. The report can be customised

### 5.2.4. Relationships/Queries:

- These are the tools used to link data tables in a database
- There are different types of relationships that can be created in a database; “One-to-One”, “One-to-Many” and “Many-to-Many” (see figure 43 below for further explanation on each type).
- This is the aspect of a database that makes it an exceptionally powerful system.

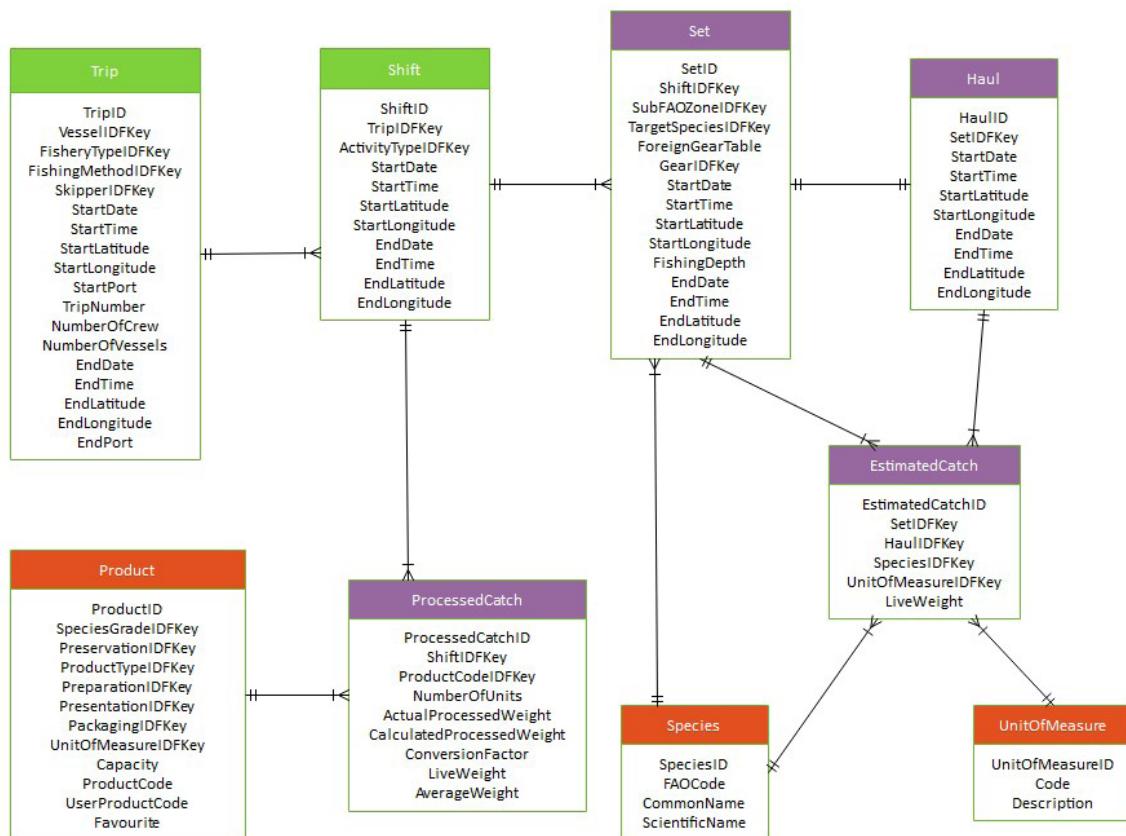


Figure 43: An example of a section of the database designed for the African Union (AU) showing relationships between data tables depicted by One-to-One and One-to-Many. No Many-to-Many relationships are found in the database designed for the AU.

### **5.2.5. Codes:**

- When creating a database for something as complicated as fisheries data it is important to ensure all captured data is standardised.
- This is normally done making use of codes that are internationally used to describe certain data.

**Discussion:** What examples can you give where the lack of standardised codes have or could potentially have a detrimental effect on the data collected.

For a more comprehensive introduction, the reader is referred to textbooks on databases (e.g. Arte 1988 and Date 1995).

The best way to understand these terms is to see them in action. The next section will focus on the newly designed database for the African Union and a chart of some relationship tables will be shown as part of the PowerPoint presentation.



## 6. PROPOSED DATA MODEL FOR AU FISHERIES

As described in the section preceding this, the use of a relational database provides fisheries managers with a powerful tool for effective management of fisheries data. This platform allows fisheries managers the opportunity to promote regional fisheries management strategies as the data collected by all African Union nations would be uniform, in a single format and meaningful. The African Union has recognised the effectiveness on regional fisheries management, with some AU nations already implemented and actively participate in cooperative regional management plans. To better facilitate this the African Union has commissioned the development of a fisheries database that would allow for the entry of relevant fisheries management data for all marine (Industrial, Artisanal and Subsistence) and freshwater (Artisanal and Subsistence) fisheries taking place within the waters governed by nations that make up the African Union.

### Activity 6.1

As a class we will work through the database design chart identifying some of the terms we have gone through and what they mean in the context of the database.

- Codes
- Relationship
- One-to-One relationship
- One-to-Many relationship
- Many-to-Many relationship
- Primary Key

### 6.1. WHY WOULD YOU CHOOSE TO USE A DATABASE SYSTEM?

So the question for this section becomes “Why would you choose a database system over simply storing data in operating system files”?

While storing data in operating system files is comfortable and familiar data are often not secure and do not allow for raw data tables to be related to one another. There are many advantages to storing data in a database management system (DBMS) some of these include:

- Data independence and efficient access
  - » Data stored in a database remain independent from other data in the DBMS but the system allows for these raw data to be related to one another based on logical external schemas. The DBMS provides secure storage and time saving external retrieval systems.
- Reduced application development time
  - » The built in functions in a DBMS such as high level query functions and the ability to produce standard reports in seconds greatly reduces application development time.
- Data integrity and security
  - » Many DBMS available have access control options allow the administrator the power to effectively shield particular end-users from the raw data, greatly reducing the risk of loss of raw data. These systems also warn if updates made by the administrator violate the semantics of the data further reducing the loss of the integrity of the raw data.

All these advantages are important to fisheries management and therefore the development of DBMS was the next logical step in the advancement of fisheries management in the African Union.

### Activity 6.2

In groups discuss some of the ways in which using a DBMS may positively (or negatively) affect fisheries management in your country.

- List these so we can discuss them with the class.

## 7. REFERENCES

Boyd and Charles (2006)

Cadima, E.L. Fish stock assessment manual. FAO Fisheries Technical Paper. No. 393. Rome, FAO. 2003. 161 pp.

Coding of latitudinal-longitudinal grid is standardised world-wide (ICCAT Field Manual for Statistics and Sampling, 1990; See FAO 1999)

The Harmonised Commodity Description and Coding System (Customs Co-operation Council, 1992) (see World Customs Organisation)

The FAO Standard Common Names and Scientific Names of Commercial Species (FAO-FIDI)

## APPENDIX 1

Summary of Fisheries Management Terms used in the text of the AU-IBAR Fisheries Training manual

**Age and size at maturity:** The age or size (length/width) at which fish or crustaceans of a given population mature for the first time. The parameter is generally calculated as the size or age at which 50% of the population is mature.

**Age or size at recruitment:** This is essentially the same as Size or age at first capture assuming that one is referring to recruitment to the fished stock rather than recruitment to the general population. The latter recruitment is of no significance to calculations of potential offtake by the fishery.

**Biomass at MSY:** The population size or biomass which produces maximum sustainable yield  
CPUE – Catch Per Unit Effort is the catch of fish in numbers or weight taken by a defined unit of fishing effort. Effort is quantified as a specified gear type in a specified period of time e.g. fishing boat for one day.

**F0.1 Strategy:** This strategy attempts to take into account the decrease in marginal YPR as fishing effort (assumed to be proportional to fishing mortality) increases. F0.1 is the fishing effort or the fishing mortality rate corresponding to 10% of the slope of the yield-per-recruit curve at the origin. The F0.1 reference point was conceptualized as a biologically precautionary target.

**Fopt :** The Optimum level of fishing effort: This is the level of fishing effort, which produces the maximum yield (MSY). It is also referred to FMSY

**Carrying capacity:** A key assumption underlying many management decisions in modern fisheries is that an unexploited fish resource has a natural population size or Biomass which is determined by the carrying capacity (K) of the environment. The biomass at the environment carrying capacity is  $B_0$

**K:** von Bertalanffy growth coefficient: This is a parameter of the von Bertalanffy growth function, expressing the rate (1/year) at which the asymptotic length or  $L_{inf}$  is approached.

**$L_{\infty}$  or  $L_{inf}$ :** This is the that the fish of a population would reach if they were to grow indefinitely (also known as asymptotic length). It is one of the three parameters of the von Bertalanffy growth function.

**M and F:** Natural Mortality and Fishing Mortality: All living organisms eventually die. All causes of death of marine organisms which are not man-induced are regarded as natural mortality (M). The cause of such mortality is seldom old age, but more commonly predation by other species or by members of the same population (cannibalism), disease, or injury due to a mechanical stress. The natural mortality of most marine organisms is very high when they are very young and vulnerable to predation. The rate of natural mortality normally declines as individuals grow older. All mortality caused by fishing is classified as fishing mortality (F). This includes fish which die as a result of fishing operations and which are not necessarily landed and recorded as part of the catch.

**MER:** Maximum Economic Rent: Sustainable fisheries are not necessarily profitable because, as with any other production operation, in order for fishing to be profitable the value of the catch has to exceed the cost of fishing. Fisheries economists prefer to use the term “Economic Rent” to describe the difference between the value of the catch and the cost of fishing. Economic rent is a term in economics which allows one to talk about the economic viability of an industry without using the word “profit”. Profit itself is a complex quantity calculated on the basis of a large number of variables for a variety of motives. In addition, the overall profits of a fishing company may be of passing interest for this chapter because the company may have other fishing related operations (e.g. fish processing, marketing operations) not concerned with the harvesting process itself, but which contribute to the profit margin. The economic viability of the harvesting process would therefore not necessarily be reflected in the company’s declared profits. From a fisheries management point of view one is really most interested in the value of the catch at its first point of sale, minus the variable costs incurred in landing this quantity of fish.

**MEY:** Maximum Economic Yield: The maximum economic yield is the value of the largest positive difference between total revenues and total costs of fishing (including the cost of labour and capital). MEY is typically achieved at catches that are 10-20% smaller than MSY. MEY is essentially a sustainable harvest level that maximises revenue from fishing or generates the largest value of sustainable catch.

**MSY:** Maximum Sustainable Yield: In a particular habitat or environment a fish population will grow in weight until it approaches the maximum carrying capacity of the habitat after which its increase in weight ceases as the stock size =  $B_0$ . At this point the number of fish recruiting into and growing up in the population is equal to the number of fish dying of natural causes. When fishing starts on the population the biomass is reduced. The number of fish dying naturally will be less but the number of fish recruiting into the population does not change so the amount of fish entering the population is greater than the amount of fish dying. If fishing was then stopped the number of recruits would increase the Biomass back to its carrying capacity level. The only way to keep the Biomass at a level below carrying capacity is to remove the excess recruitment by fishing (i.e. harvest the excess production). This excess production is known as sustainable yield, and if it is not all removed, then the population biomass will increase. For this reason, the sustainable yield is also called the surplus production. For each resource there is some population size at which the surplus production/sustainable yield reaches a maximum value. This population size is called BMSY, and the corresponding maximum value of sustainable yield is known as the “maximum sustainable yield” or MSY.

**OSY:** Optimum Sustainable Yield: The optimum sustainable yield is a term has its roots in fisheries management legislation drafted in the USA. It refers to a sustainable yield level for managing a fishery which takes into account a wide range of economic and social factors. The variable costs of harvesting addressed in the definition of economic rent is just one such factor.

**SBPR:** Spawner Biomass Per Recruit: Spawning stock biomass per recruit estimates the expected lifetime reproductive potential of an average recruit which is an important indication of population growth potential.

**Size at first capture:** This the size of an organism (Fish length or crustacean length or width) when it first becomes available to the fishery. Yield from a fish stock is directly related to the length (or age)

at which a fish or crustacean first becomes vulnerable to the fishing gear.

**TAC:** Total Allowable Catch: Generally some kind of control must be exercised over the exploitation of marine resources. The obvious control tool is a limitation on the total amount that can be caught each year (i.e. the allocation of total allowable catch - abbreviated as TAC).

**Economic rent:** The difference between the value of the catch and the variable costs incurred in producing that catch is known as economic rent. This is a quantity which can usefully be compared from one situation to another for a particular fishery.

**Sustainable economic rent:** The economic rent that is obtained by harvesting the sustainable yield from a fishery, i.e. it is the difference between the sustainable yield and the harvesting costs.

**Total Catch:** Numbers or weight of fish represents the removal of biomass and individuals from the ecosystem, and is the fundamental impact fishing has on fish populations.

**YPR:** Yield Per Recruit: Determination of the appropriate age at first capture for a particular fish stock involves a trade-off between two factors: the increase in mass of an individual fish as it gets older and the parallel increase in the probability that it will be eaten by a predator. The Beverton-Holt model describes this trade-off in terms of Yield per Recruit which can be translated to total yield if it is assumed that recruitment is the same from year to year. The principal purpose of yield per recruit models is to get an idea of the effect of selection pattern and fishing mortality on the yield from a fixed number of individuals that enters the fishery. They often provide reference points for management purposes.





African Union – Interafrican Bureau for Animal Resources  
(AU-IBAR)

Kenindia Business Park  
Museum Hill, Westlands Road

PO Box 30786

00100 Nairobi

Kenya

Tel: +254 (20) 3674 000

Fax: +254 (20) 3674 341 / 3674 342

Email: [ibar.office@au-ibar.org](mailto:ibar.office@au-ibar.org)

Website: [www.au-ibar.org](http://www.au-ibar.org)