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BIOECONOMIC ANALYSIS OF ARTISANAL MARINE FISHERIES OF TANZANIA (Mainland)

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ABSTRACT

Artisanal marine fisheries of Tanzania involve the majority of the coastal population whose survival is entirely dependent on the coastal fishery resources. In this paper the artisanal sector of the marine fisheries for the period 1987 -2000 is analysed by applying Gordon-Schaefer Surplus Production Model on time series of total catch and standardised effort. Static reference points such as open access equilibrium, maximum economic yield and maximum sustainable yield are established in addition to the more dynamic optimal yield solution. The results show that the fishery has expanded beyond the economically optimum point where the current level of effort is further beyond that of maximum sustainable yield resulting in suboptimal yield, i.e. it has been evident that there is already overfishing in the inshore waters where majority of artisan fishermen concentrate. The major constraint is assumed to be the inadequate institution and legal framework for fisheries management. Also social and equity considerations have been the bottlenecks for the implementation of regulatory measures which would cause further unemployment. Thus, the present study calls for policy intervention to rescue the stock from the existing high fishing pressure that would lead to depletion.

KEYWORDS: artisanal fisheries, efficiency, optimality, sustainable fishing, overfishing, bioeconomic model, maximum economic yield, optimal sustainable yield, maximum sustainable yield, open access equilibrium, catch per unit effort.

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CHAPTER ONE

1.0 Introduction

Worldwide fishery is of immense importance and most of the coastal people depend on fisheries for their livelihood. It is historically known that artisanal fisheries have provided the economic foundation for most countries of the Southwest Indian Ocean region (Mapunda, 1993). The artisanal fisheries are by far the most important fisheries in the marine sector of Tanzania. According to MNRT report, they contribute for over 95% of the total marine catch (Anon., 2000a).

The waters of the Southwest Indian Ocean region possess few rich fishing grounds, both in terms of total size of biomass of commercial species like tuna and in terms of density (Sharp, 1982). While it is true that fish qualifies as a renewable resource, it is not necessarily an inexhaustible one (Hartwick and Olewiler, 1998). Annual catch can be sustained indefinitely as long as it equals annual net growth. As such, Maximum Sustainable Yield (MSY[1]) can be achieved.

Another aspect of fish resource utilization going to be considered here is the maximization of economic rent. That refers to attaining the economic equilibrium, which is referred to as the Maximum Economic Yield (MEY[2]). Conrad and Clark (1987) stated that the relative economic efficiency of the fishing industry has significantly declined in many countries in recent years partly due to overexploitation and the consequent reduced yield from many fish stocks. Overfishing and waste of resource rent in fisheries are caused by free and open access to the resource exploitation. In reality, open access is common in Tanzania's marine artisanal fisheries (Keen, 1991).

Tanzanian marine artisanal fishery is characterized by conditions of crowding where the available coastal resources are exploited by a large number of fishermen (Tarbit,

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[1] MSY refers to the catch level, which if maintained perpetually would produce the largest annual harvest or net benefit.
[2] MEY is the sustainable level of catch that produces the greatest economic profits.

1986). Fishermen and fishing effort increased in number so long as fish catches commanded high prices in the market due to high demand that exists for both fish and fish products (Bagachwa and Maliyamkono, 1994). Artisanal fishing intensity has been increasing in the inshore waters due to the limitation of the range of fishing vessels and lack of proper management practices, resulting in excessive effort (Jiddawi, 2001). However, as Linden and Lundin (1996) pointed out that, during the course of time high levels of fishing effort cause a serious reduction in the size of the fish stock and consequently the rate of catch per unit of effort is reduced. In other words, as will be argued in this paper, overfishing and resource rent dissipation are the likely outcomes. Mapunda (1993) already found out that while the marine fishery has not been able to fully exploit its annual potential, there are ample signs of overfishing in the coastal waters. Also a decline in catches of certain commercial species mainly reef fishes has been reported by Anon. (2001a). This suggests that the fishery is being over-fished, and that better fishery management needs to be imposed in order to maintain productivity of the fishery resource on a sustainable basis.

This study, therefore, tries to show whether or not overfishing indeed exists. A literature review of the Tanzanian marine fisheries with particular emphasis on the artisanal sector is presented in chapter 2. Chapter 3 summarizes the basic theory and model of fishery resource exploitation applied for the study. The data used in the study is outlined in chapter 4 while chapter 5 presents the results of the study. Finally, chapter 6 presents discussion based on the results while chapter 7 provides summary and policy recommendations.

1.1 Rationale of the Study

Tanzanian marine artisanal fishery is the main economic activity of the coastal people due to the lack of alternative sources of subsistence. This sector is characterized by open access where there is crowding of effort in the coastal waters, which is attributed to the lack of technical skills and capital on the fishermen side to go further beyond the inshore waters. Besides, the overall picture of relative fish prices is that they have risen significantly faster than the prices of other goods, which attracted more efforts. Fishermen like any other economic agents are driven by the profit maximization objective at least in the short run (Conrad and Clark, 1987). Therefore, it is true to believe that fishermen and fishing efforts increased in the inshore reefs in response to the cost limitations and the high prices in the market. This problem coupled with lack of enforcement of existing management measures would possibly lead to overfishing. Therefore it is now timely to know whether the fisheries can be sustained at the current exploitation level and whether society could gain from a reduction in fishing effort.

1.2 Objectives of the Study

The present study was undertaken with such objectives as:

- Analyzing the artisanal marine fishery of Tanzania using historical data;
- Examining the gear composition of the fishery with respect to relative catch contribution;
- Determining the different key reference points like MEY, MSY, OSY[3] and OAY[4] and their corresponding effort levels by applying theoretical bioeconomic model.

The study is based on empirical investigations that has provided insight into such questions as:

- Are the present fish harvesting levels in the marine waters sustainable?
- If fish harvesting is at levels that are unsustainable, what management measures could be drawn to ensure sustainability in the long run?

Specifically, this paper tries to identify the main causes influencing decline in catches, change in catch/size composition, changes in gear composition, and disturbance of the marine ecology.

[3] OSY (Optimum Sustainable Yield) refers to the catch level which maximizes social welfare.
[4] OAY (Open Access Yield) refers to the catch level where total revenues are equal to fishing costs.

1.3 Significance of the Study

The importance of fishery resources to the economy of Tanzania cannot be understated. These resources make a significant contribution to the Gross Domestic Product (GDP), foreign exchange earnings, provide both direct and indirect employment and supply relative cheap protein to the population. The findings of this study will fill the existing gap of empirical studies that focus on the bioeconomic analysis of sustainable use of fishery resources in Tanzania. The information is also expected to assist policy makers and interested parties to make informed decisions about the management of fisheries. The experience can be extended to similar situations of overexploitation with regards to other marine resources and other renewable resources in general.

CHAPTER 2. BACKGROUND

2.1 Marine Fisheries of Tanzania

The coastline of Tanzania stretches for approximately 800 km on the continental side and, on moving from north to south, passes through the Regions of Tanga, Coast, Dar es Salaam, Lindi and Mtwara. The marine fisheries are composed of artisanal fisheries carried out by the people of coastal areas, and industrial fisheries based around Dar es Salaam.

In terms of production, the main share of the marine catch is artisanal landed using traditional fishing craft and gear according to MNRT report (Anon., 2000a). These are dugout canoes, outrigger canoes and plank boats. Gears include nets, hooks-and-line, traps (Anon., 2001a) and some fishermen illegally use explosives (UNEP, 1989).

Total catches reach up to 50,000 mt for Tanzania mainland while the potential is estimated about 80,000 – 100,000 mt (Anon., 2000b) and it is composed of mainly sardines, anchovies, mackerels, kingfish, emperor, grouper, snapper, sharks, rays, shrimp, lobster and sea cucumber (Jiddawi, 2001). It is estimated that over 20,000 fishermen are engaged in artisanal fisheries along the coast of the mainland part. Generally, about 500,000 people directly or indirectly depend on the success or failure of the industry (Bagachwa and Maliyamkono, 1994).

2.1.1 Economic Contribution of the Fishery Sector

Artisan fishing is the main economic activity of the majority of the people living along the coast of Tanzania stretching from Tanga in the north to Mtwara in the south (Tarbit, 1986). It provides an important source of income, food and employment opportunities, directly as well as indirectly. Commercial fishing along the coast also contributes significantly to employment opportunities and foreign exchange earnings (Bakari, 1997).

Tanzania exports marine fishery products such as shrimp, sardines, sea cucumber, tuna, shells, lobsters, crabs, squids, octopus and aquarium fish (Anon., 2001b). In

1999 marine fishery products accounted for 13% and 2% of fish exports and of total exports, respectively. Contribution of fisheries to the country's GDP is 2.1 – 5%. This is small compared to that of agricultural products like coffee and cotton, which is estimated about 25%. However, it provides an important source of employment and it comprises about 30% of the total animal protein consumption of the population. Per capita fish consumption is in the range of 6 – 8 Kg/year (Anon., 2001a).

2.1.2 Natural Environmental Variables

The continental shelf of mainland Tanzania, of which about two-third has fringing reefs, is often close to the shoreline and broken by river mouths such as the Ruvu and Rufiji. It is generally narrow with the 200m-depth contour being about 4 km offshore, except for the Zanzibar and Mafia Channels where the shelf extends for some 60 km (Mgaya et al., 1997). According to Mongi (1991), the area of the shelf (mainland & Zanzibar combined) is estimated to cover 30,000 Km^2. This is the area most commonly used by artisan fishermen.

Such major rivers as Ruvu, Rufiji, Pangani, Wanii and Ruvuma together with several smaller systems provide a major source of nutrient supply to adjacent inshore waters. Peak outflow from these rivers normally occurs between March and November (Iversen et al. 1984). The continental shelf is characterized by sandy/muddy tidal flats, mangroves, coral reefs, rocks intertidal platforms, sea grass beds, lagoons and estuaries (Nhwani, 1987). These are important habitats for a variety of fishery resources.

The coastal area is characterized by a tropical hot and humid climate dictated by two distinct seasonal monsoon winds. A hot and wet season occurs from about November to March when annual rainfall ranges from about 800 to 1000 mm and a Northeast Monsoon (Swahili - "*Kazikazi*") predominates. A cooler dry winter season occurs from May to October when Southeast Monsoon (Swahili - "*Kusi*") prevails. Wind strengths are normally higher (Beaufort force 4-7) and more persistent during the Southeast Monsoon period where air temperature decline and humidity decreases. Under the force of persistent winds and lower air temperatures; heat is lost from the water, thermocline[5] is driven to greater depths up to 120 m and the water above this line becomes almost completely mixed. As a result, nutrients are circulated into the top (euphotic) zone and phytoplankton bloom. The seasonal trade winds decline in strength by October (Beaufort 1-4) accompanied by an increase of air temperature resulting in the formation of stable thermocline at smaller depths of 50m (Newell, 1957). During inter-monsoon periods, wind direction can be variable but overall conditions tend to be calm.

The East African Coastal Current is important for larval dispersal and downwelling along the East African coastline, but its main influence is offshore. Of greater influence on inshore bay areas, open fringing reefs and inlets are local semi-diurnal tidal currents. Tidal currents combined with inputs from many rivers but especially the Rufiji and Ruvuma provide a major source of food and nutrients to adjacent inshore waters (Mongi, 1991). Mean surface sea temperatures range from 25 - 29^0 coinciding with the end of the dry and wet seasons respectively while surface salinities reach their maximum and minimum during November and May, respectively (Newell, 1957).

2.1.3 Technical Characteristics of the Fishery

Tanzanian marine fishery is composed of mainly artisanal fishery carried out by the coastal communities where entry into the fishery is free, and industrial fishery based around Dar es Salaam. The artisanal sector is characterized by use of local, traditional and primitive methods of fishing (Mochii et al., 1998). By implication, the characteristics of the sector are supposed to be low level of mechanization, labour intensive fishing methods, and the prevalent use of unsophisticated techniques.

The industrial fishing comprises a small fleet of steel-and wood-hulled trawlers and purse seiners. Trawling for shrimps and purse seining for sardines expanded rapidly in the late 1980’s up to early 1990’s (FAO, 1997). This sector is intended to export its products and is mainly based on prawn trawling. About 20 trawlers (34-146 GRT ton) based in Dar es Salaam carry out fishing operations.

[5] Thermocline refers to the interface of warm low-density water and cool dense water below, where there is abrupt change in heat or temperature.

Despite remarkable differences between the artisanal and industrial sectors, they often interact as their fishing grounds are generally the same, which often tends to raise conflicts between the two sectors (Sobo, 1998). But there is no overlap in species they exploit except for prawns.

2.2 Artisanal Marine Fisheries

Fig 2.1 Map of Tanzania showing the Study Area i.e. the coastline where Artisanal Marine Fisheries are carried out.

2.2.1 Artisanal Fishing Community

Over 20,000 fishermen are engaged in the artisanal fisheries at 210 fishing villages and landing sites located in the entire coast including Dar es Salaam (Anon., 2001a). Besides, there are occasional fishers harvesting fish for their own consumption, and part-time fishers who tend to use a range of fishing gear and usually operate their fishing as a consequence of lack of work in their main occupation.

Some artisan fishermen work alone, but usually they are organized in small crews. Mostly they are confined to a short range of operation from their outports (Mapunda, 1993). The duration of their trips is counted in hours only, as they seldom stay out overnight. The length of the fishing season varies with weather conditions along the coast where rough weather curtails the number of days on which fishing is possible (Tarbit, 1986). Also, the fishermen are engaged in other economic activities such subsistence farming as growing cassava, sweet potatoes, sisal, maize, and; raising such domestic animals as goat, cattle and poultry to supplement their low fishing incomes (Y. Mgawe, pers. comm.).

2.2.2 Fishing Craft and Gear

There are about 6000 fishing boats of which almost half of them are dugout canoes (*mtumbwi*), one quarter are outrigger canoes (*ngalawa*); and the remained quarter are planked construction boats such as *mashua*, *dau*, and *boti*. The main means of propulsion are by paddle, pole or sail, with engines being used in only a few boats due to limitations of cost and maintenance (Mochii et al., 1998). As a result, motorized boats account for approximately 10% of all the artisanal fishing boats.

Fishing gears include hand line, gillnets, longline, seine net, ring net, cast net, fish traps and spears (Anon., 2001a). Handline fishing is the most prevailed method in terms of number of fishermen engaged, and targets relatively high priced reef fish and the fishing costs are very low. Small meshed nets (5-10cm) consist of bottom gillnet and floating gillnet used around coral reefs and estuaries. Entanglement nets (*Jarife*) with mesh size of 15-20cm are used as drift or floating gillnets to catch sharks. Seine nets are used either from the beach or in open water reef areas. This fishing method damages reef and sea grass areas when the nets are dragged on the bottom, and due to the small mesh size that provides a catch mainly of immature fish (Mgaya et al, 1997). Ring net fishing (1-1/2 inch mesh) for small pelagic fishes is the most productive method in terms of catch volume and its output accounts for about 25% of the total production of marine artisanal fisheries.

Generally, there is wide spread use of fishing practices that pose significant damage to the reefs and sea grasses. According to Jiddawi (2001), these include dragged nets, dynamite fishing, and use of spears. Also collection of marine products like sea cucumber, octopus, bivalves and shellfish is conducted with out size limitations.

2.2.3 Species Caught

Marine catches are represented by multiple species where reef fishes such as emperor (*Lethrinidae*), rabbit fish and parrot fish (*Siganidae*), snappers (*Lutjanidae*) and grouper (*Serranidae*) alone make up one-third of the overall catch indicating that shallow reef waters are used as the main fishing grounds. Approximately one-third of the total catch is accounted for by small pelagic fish such sardines (*Clupeidae*), anchovy (*Engraulidae*), small mackerel (*Scombridae*) and horse mackerel. These are subject to large demand as they are much cheaper than others. Large pelagic fish species mainly include jacks and trevallys (*Carangidae*), kingfish (*Scomberocoridae*), tunas, mullet, swordfish, and silver biddies. Other important species are sharks and rays, crustaceans (shrimp, lobster and crab), octopus, sea cucumber, gastropods, bivalves and shellfish. Generally, the catch compostion is multispecies with out evidence of a dominant species (Anon., 2001a). According to Mgaya et al (1997) the main targets of the fishery are those that are large and usually long-live predators high up in the food chain like emperors, snappers, groupers, jacks, trevallys, swordfish, kingfish, sharks and rays.

2.2.4 Productivity in the Artisanal Fisheries

The continental shelf is generally narrow; hence fish productivity is low, as it doesn’t well support larger biomasses (Keen, 1991). Artisanal catches reach up to 50,000 tons, and most of the inshore fishery resources are overexploited (Linden and Lundin, 1996). As a result, any increase or decrease in fishing effort at the margin of the artisanal fisheries has little effect on the immediate total catch, as the most productive sites remain fully exploited. Jiddawi (2001) also stated that artisanal fishery resources have already reached upper level of exploitation. This is believed to be due to fishermen fishing in the same areas since time immemorial because of limitation of the range of their fishing vessels that are not powered by motor engines, and due to lack of proper management practices (Jiddawi, 2001).

2.2.5 Markets and Distribution

The total amount of fish marketed from the marine sector is estimated to be with in the vicinity of 35,000 tons where close to 80% of the fish is sold as processed fish and the remaining as fresh fish (Rupamoorthy, 1991). A review of the conditions of fish supply and demand in Tanzania has shown that fish supply volume for the population has firmly dropped in recent years in the face of stagnating fish supply, and increased population (Anon., 2001a). According to FAO statistics, the per capita fish consumption dropped from 10.7 kg in 1998 to 9.4 kg in 1999 to 5.9 kg in 2000.

At present there is no effective central marketing agency for the villages. Harvested fish are transported to the markets through various market intermediaries. The traders' visits range from daily to irregularly depending on the distances of the villages from the major towns along the coast and the city of Dar es Salaam (Bagachwa and Maliyamkono, 1994). Hence, prices of fish are attributed to the variable costs of transportation where they tend to be lower further away from the towns. Mapunda (1993) underlined that inadequate communication and lack of transport facilities have tended to create a sensitive market for the fishermen.

2.2.6 Fishery Management Practice

Nationally, the artisanal fishery is the most important sector as it lands almost all the marine catch and supports the majority of fishermen. From management point of view; however, it is the most difficult sector to manage since fishermen are spread out all along the shores, entry into the fishery is free, and normally fishing tends to be their main source of income and employment in the coastal fishing communities (Daffa et al., 1997).

Powers relating to management of fishery resources in Tanzania at all levels are vested in the Director of Fisheries Division of the Ministry of Natural Resources and Tourism. According to Sobo (1998), the legal framework regarding the exploitation of fisheries resources by artisanal fishers comprises mainly conservation measures such as:

- *Gear limitations:* where beach seines and nets with a mesh size smaller than legally permitted are illegal under the revised Fisheries Regulations of 1997.
- *Closed fishing areas:* where protected areas like marine reserves and private parks (Chumbe, Mnemba and Menay bay) have been established under the Marine Parks and Reserves Act of 1994 so as to conserve a " seed bank" of fish.
- *Zoning*: a management strategy created to reduce overcrowding of fishing vessels or fishing efforts in the most productive areas especially if the fishing area is small (Linden and Lundin, 1996). This is meant to minimize or avoid potential conflict between industrial vessels and artisanal fishers.
- *Licensing of vessels and gear*
- Finally, use of explosives, poison, and other destructive fishing methods like spear is illegal under the Fisheries Act of 1970.

However, very few are aware of the laws that govern fishing activities to the extent that when laws are enforced they perceive them as constituting harassment. In principle, fishing methods such as beach seines, nets of illegal mesh size, dynamites and spear; and unlicensed fishing are prohibited, but law enforcement is difficult to achieve as the capacity to manage widely scattered fishing grounds is limited (Sobo, 1998).

CHAPTER 3. MODEL

3.1 Needs and Importance of Models

Prediction models are necessary for fisheries administrators to foresee in advance the evolution of the resource abundance. This is necessary for development and management measures to be taken in time (Garcia and Le Reste, 1981). Where biological data such as fish growth, mortality, age class and stock recruitment required to set up a detailed population dynamics model are not available, simple biological models like surplus production models which utilize only catch and effort data that are easy to obtain are more useful to analyse fishery dynamics (Sparre and Venema, 1992).

The study of fisheries exploitation attempted to use economic analysis on the interface between human society and the biological resources. This resulted into the development of what has become to be known as bioeconomic models, analyzing the interaction between human harvesting pressures and biological resource regeneration (Clark, 1973). Padilla and Charles (1994) defined bio-economic models as quantitative models characterized by the integration of natural and human sides of the fisheries equation, linking the biological and economic elements.

3.2 Choice of Model

More sophisticate bioeconomic models can be employed if sufficient biological and economic data are available. This was not the case for Tanzania. Due to data constraints, single species and constant price/cost model was selected for this study in order to assess the level of exploitation of artisanal fishery in Tanzania marine waters with a view of establishing whether or not there has been overfishing during 1987-2000; and determining levels on which fishing would be undertaken in efficient and sustainable manner. This model is based on the classic Gordon-Schaefer model, which assumes that growth of fish population is related to the stock biomass by a symmetrical dome-shaped function; and is employed popularly in empirical research.

3.2.1 Biological Model

A biological model of multi-species fishery is generally complex for the present study because of the quality of the data collected. King (2000) noted that in tropical fisheries where catches are made up of many different species, treating the component species as a single stock and managing the fishery to maximize economic yield may be the only practical option available. Similar procedures have been described by Hilborn and Walters (1992) where the dynamic interactions of mixed species were treated as single stock and analyzed using production models. Therefore, a model assuming single species fishery was built to calculate the maximum sustainable yield and the corresponding effort level.

An attempt to describe a long-term catch equation as a function of fishing effort was formulated by Schaefer (1954). This model was based on the assumptions of the equilibrium model. In this model the overall stock is assumed to follow a logistic growth curve; and the rate of surplus growth is defined as:

$$F(X) = rX\left(1 - \frac{X}{K}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where *F(X)* is natural growth; *X* is stock size; *K* is carrying capacity, a parameter corresponding to the natural equilibrium stock size; and *r* is intrinsic growth rate of fish. This equation is a parabolic growth curve. To obtain the maximum natural growth and the corresponding stock size mathematically, the first order derivative of equation (1) is set equal to zero as follows:

$$\frac{dF(X)}{dX} = r\left(1 - \frac{2X}{K}\right) = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Stock size of maximum sustainable yield is then $\frac{K}{2}$. Schaefer catch equation is a bilinear short-term harvest function and it assumes that effort always removes a constant proportion of the stock.

$H(E,X) = qEX$ …………………………………………….. (3)

Where H = catch measured in terms of biomass; E = fishing effort and q is a constant catchability of coefficient.

Sustainable or equilibrium yield occurs when the rate of fishing equals the rate of natural growth, i.e. when *rate of change of biomass, dX/dt = F(X) – H(E,X) = 0*. This implies $qEX = rX\left(1-\frac{X}{K}\right)$ based on equation (1) and equation (3). Biomass at equilibrium, X, is solved to be:

$$X = K\left(1-\frac{qE}{r}\right) \text{…………………………………………. (4)}$$

Inserting equation (4) into equation (3) gives rise to:

$$H = qKE\left(1-\frac{q}{r}E\right) \text{……………………………….. ……..(5)}$$

This is the long-term harvest function whose parameters can be estimated from the catch and effort data through linear regression, and it can be expressed by:

$$H(E) = aE - bE^2 \text{ ………………………………………….. (6)}$$

Where $a = qK$ and $b = \frac{q^2K}{r}$ A linear regression can be performed by converting (6) to a linear equation:

$$\frac{H}{E} = a - bE \text{ ………………………………………………. (7)}$$

Since data on catch and effort are available for the Tanzanian marine artisanal fishery, this allow us to estimate the parameters *a* and *b* by linear regression of the catch per unit of effort on effort.

Effort at maximum sustainable yield can be obtained from equation (6) by taking partial derivative of H with respect to E and setting it equal to zero as:

$$E_{MSY} = \frac{a}{2b} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8)$$

And the output at MSY is:

$$MSY = \frac{a^2}{4b} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (9)$$

3.2.2 Economic Model

Economic models of fishery are underlined by biological models. It is impossible to formulate any useful economic model of fishery with out specifying the underlining biological dynamics of the fishery (Munro, 1982). Based on constant price and unit cost of effort, the catch-effort function (6) can be converted to define revenue as a function of standardized effort units. That is, the total revenue will be calculated using the formula:

$$TR(E) = p \cdot H(E) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where *p* denotes the average price per kilogram of fish.

The relationship between cost and effort is assumed to be linear, then total cost of fishing effort will be defined as:

$$TC(E) = c \cdot E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(11)$$

Where *c* denotes unit cost of effort that includes the opportunity cost of labor and capital, and *E* the unit of effort.

The total economic rent of the fishery will be:

$$p(E) = TR(E) - TC(E) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(12)$$

At the open access point, total fishing costs are equal to total revenues from the fishery since vessel homogenousity is assumed . Then the open access effort is obtained by equating *TC(E) = TR(E)* which yields:

$$E_{OAY} = \frac{\left(a - \frac{c}{p}\right)}{b} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

Maximum economic return is realized at a lower total fishing effort since positive economic rent only is obtained at efforts lower than E_{OAY}. Maximum economic yield (MEY) is attained at the profit maximizing level of effort which is obtained using equation (12), $p'(E) = 0$ or $\frac{dTR(E)}{dE} = \frac{dTC(E)}{dE}$. Therefore, the effort at maximum economic yield is:

$$E_{MEY} = \frac{\left(a - \frac{c}{p}\right)}{2b} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)$$

3.2.3 Bioeconomic Dynamic Model and the Price of Time

While including time as a variable, it is possible to establish dynamic reference points in addition to the static reference points MSY, MEY and OAY. Present valuation of capital flow over time depends on the discount rate, d . The discount rate would therefore determine the stock level maximizing the present value of the flow of resource rent over time. This reference point is referred to as the optimal economic yield biomass.

Sustainable resource rent as a function of biomass, *X* is expressed as:

$$p(X) = \left[p - \frac{c}{qX}\right]F(X) \text{, when H = F(X)} \ldots\ldots\ldots\ldots\ldots\ldots(15)$$

The present value of flow of net revenues in a time interval (0, ∞) will be:

$$PV_p = \int_0^{\infty} p(X) e^{-dt} dt \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

Maximisation of the present value (16), one yields:

$$d\left[p - \frac{c}{qX}\right] = \frac{dp(X)}{dX} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Inserting (15) into (17) yields $F'(X) + \dfrac{\dfrac{c}{qX^2} \cdot F(X)}{p - \dfrac{c}{qX}} = d$

Differentiating equation (17) leads to a quadratic function where the optimal stock level, X^*, is a positive root and depends on the parameters *c, p, q, r, K* and d according to the following relationship:

$$X^* = \frac{K}{4}\left[\left(\frac{c}{pqK} + 1 - \frac{d}{r}\right) + \sqrt{\left(\frac{c}{pqK} + 1 - \frac{d}{r}\right)^2 + \frac{8cd}{pqKr}}\right] \qquad (18)$$

Optimum biomass, X^* decreases as d increases, and consequently will approach the biomass at bionomic equilibrium (open access) for $d \to +\infty$. The optimal sustainable yield (OSY) and optimal effort level (E_{OSY}) for a given price of time d are then obtained by:

$$OSY = r \cdot X^* \left(1 - \frac{X^*}{K}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (19)$$

$$E_{OSY} = \frac{OSY}{q \cdot X^*} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (20)$$

3.3 Limitation of the GS Model

The model developed in this study is an ecosystem equilibrium model that assumes constant environmental conditions. However, the overall stock under study is a complex composition of fish species that depend on several ecological conditions like food supply, water temperature, currents, disease, pollution and so on. In other words, multispecies tropical fishery constitutes a high degree of biological interaction and also technical interaction where a gear applied on a particular species is bound to indiscriminately cause mortality on others (Pauly, 1979). The overall sustainable effort level estimated based on this model could lead to biological overfishing of some species while others are favoured (Jennings et al, 2001). The model therefore is limited in its usefulness as operational tool in managing tropical fisheries that reach commercial size at varying ages.

Despite these limitations, however, as Hannesson (1993) noted this model can produce rough guidance on desirable fishing effort and has great values for crosschecking the results of other modeling approaches that rely on larger data sets.

CHAPTER 4. DATA AND PARAMETER ESTIMATES

In order to carry out the study, time-series of data (1987-2000) was gathered on the following variables, namely, (i) the total or aggregate catch, (ii) the effort, and (iii) the average price of fish. These were obtained from the Statistics section of the Fisheries Division. Catch was expressed in weight of biomass in metric tons; while effort, which is a composite of input, was expressed in terms of number of gears. With regard to fish price, average value was taken. On top of these, informal discussion was held with fishermen and fishery officers to gather their perception on the past and present level of exploitation of the fishery.

4.1 Fishing Effort Data

Wide varieties of fishing gears are used by the artisan fisherfolks. These range in size and cost of investment from ring nets to handlines and fish traps. In terms of volume of catch landed, the most important fishing gears are ring nets, gill nets, longlines, handlines and seine nets.

Table 4.1 Fishing Gears by Type and Number

Year	Gillnets	Shark nets	Beach Seines	Hand lines	Long lines	Purse Seines	Ring nets	Cast nets	Scoop nets	Fixed Traps	Basket Traps
1987	6955	3193	1087	7098	135		34	510		3052	5056
1988	7425	3249	832	8710	201		56	643	74	176	6351
1989	7810	3451	690	10708	278		50	645		233	6910
1990	8042	3556	1225	11357	287		96	674		167	8759
1991	8509	3830	651	12078	310		94	403		234	7888
1992	6955	3527	537	7083	223	10	92	124		34	5813
1993	4488	3327	537	5672	193		92	144	75	34	5015
1994	5280	3327	537	6853	193		92	144	71	34	5593
1995	6120	3557	550	9839	5980		221	149	158	25	6995
1996	8620	3757	560	11957	6575		231	153	158	135	5693
1997	8950	3810	558	12512	6802	40	234	170	145	176	5628
1998	9325	3863	544	12983	6834	57	248	195	256	254	6299
1999	9525	3863	567	12983	6972	57	268	217	256	254	6299
2000	9756	3892	575	13782	7251	68	280	233	282	280	6557

Source: Fisheries Division, Ministry of Natural Resources and Tourism

4.2 Trends in Real Effort

The following figure shows the total numbers of the most important gears as units over time.

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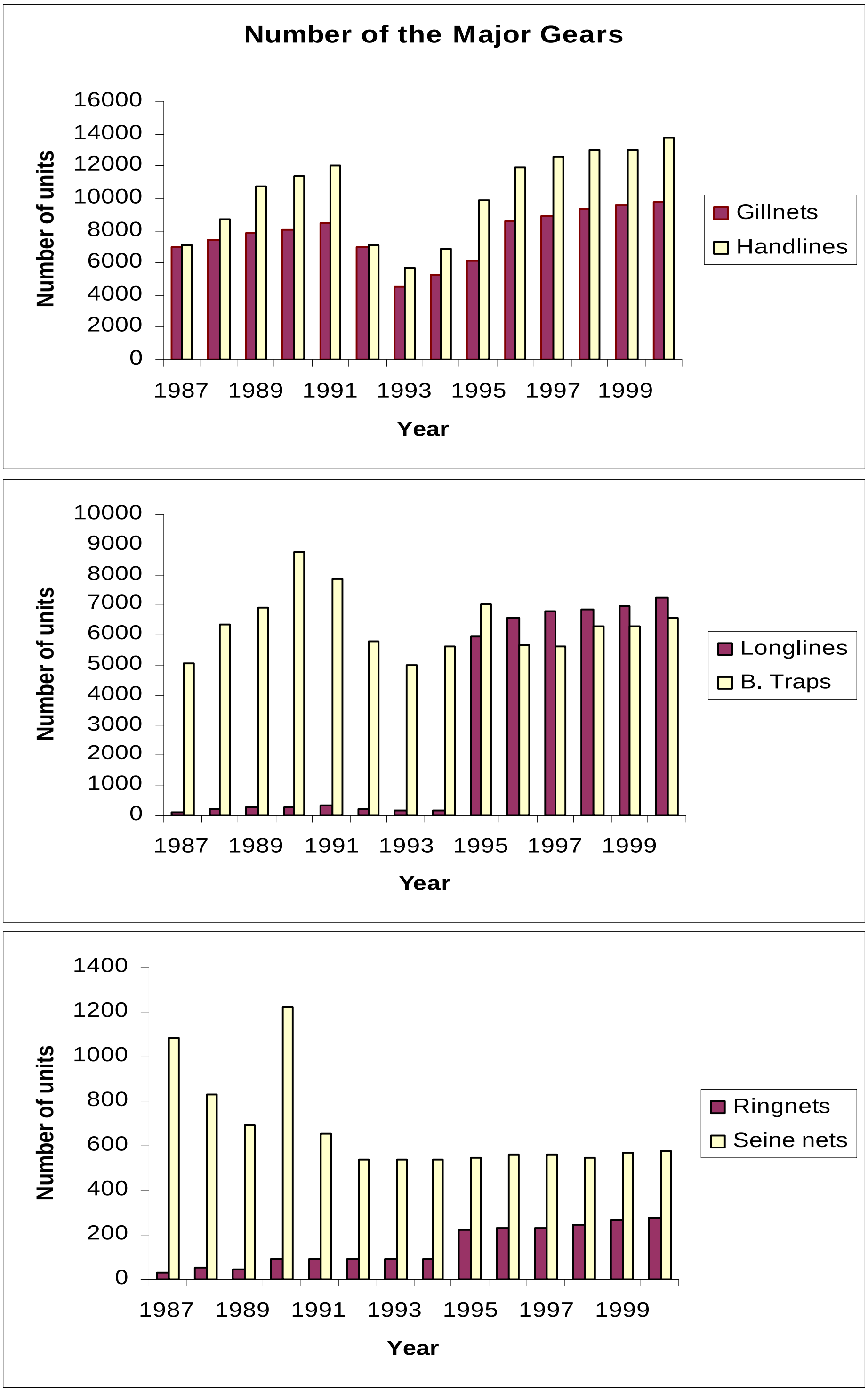

Fig. 4.1 Trends in the Main Fishing Gears.

Since 1990 seine nets have been declining significantly due to the official ban of their use; while ring nets, although still small in number, have been increasingly becoming more important. Similarly, longlines have showed a dramatic increase in mid 1990's. Traps, however, seemed to be more or less constant over the years. By and large, there has been a sharp increase of gears mainly gillnets and handlines during 1989 – 1991 due to high influx of fishermen and fishing vessels from neighbouring Zanzibar and Mozambique. This was followed by an abrupt decline of effort until 1995, but later these gears together with longlines tended to continuously rise.

4.3 Standardized Effort Data and Parameter Estimates

In order to get one measure of fishing effort for the annual total catches, the effort values from individual gear types had to be converted into standard effort units. Due to the variability of the fishing gears in the fishery, the study treated ringnets, gillnets and longlines independently; whereas handlines, shark nets, seine nets, traps, cast nets and the likes were altogether treated under the same group "others." The stock was assumed to follow logistic growth and the total standardized effort (E) is the number of gears (e_i) multiplied by a standardizing weight (w_i) summed for all gear groups (i), $E = \sum_i wi \cdot ei$. By inserting the standardized effort, E, into equation (7), catch parameters a and b that provided best and unbiased linear regression were estimated by performing regression analysis.

Table 4.2 Estimated Parameters

Model	***a***	***b***	**R^2** (adjusted)
Schaefer	0.0261026 (45.99)	3.13526E-06 (19.13)	0.97

The adjusted R^2 indicated that the obtained gear specific standardized fishing efforts explain much of the variation in the total catch.

Table 4.3 shows standardizing weight for some of the major gears, while standard effort units performed by the gears and total catch figures are shown in Table 4.4.

Table 4.3 Estimated Standardizing Weights for some of the major gears.

Gear	Standardizing weight
Ring nets	2.661305
Gillnets	0.057321
Longlines	0.061969

Table 4.4 Standardized Effort and Catch data

Year	Ring nets	Gill nets	Longlines	Others	Total Stand. Effort units	Total Catch
1987	90	399	8	1652	2149	39990
1988	149	426	12	1939	2526	46860
1989	133	448	17	2232	2830	47145
1990	255	461	18	2435	3170	54526
1991	250	488	19	2409	3166	52380
1992	271	399	14	1414	2098	42183
1993	245	257	12	1184	1698	34227
1994	245	303	12	1385	1944	37286
1995	588	351	371	1986	3296	48762
1996	615	494	407	2354	3870	58500
1997	729	513	422	2864	4528	52540
1998	812	535	423	3095	4864	51230
1999	865	546	432	3107	4950	52100
2000	926	559	449	3478	5412	49900

(Total catch figures are adapted from the Fisheries Division, Ministry of Natural Resources and Tourism)

4.4 Catch Trends

Artisanal marine landings in Tanzania increased from 39,900 tons in 1987 to 54,526 tons in 1990. In other words, between these years there was an increase of 37 % in fish landings by artisan fishers. This may have been the result of the rise in fishing effort during the late 1980's which continued up to 1990. With exit of considerable effort during early 1990's, however, catch greatly declined to as low as 34,227 tons in 1993. Percentage wise catch declined by 37 % between 1990 and 1993. It then tended to rise until the maximum level was reached in 1996 where 71 % increase was achieved from its highest drop in 1993 and later somehow stabilized in the late 1990's which seems to indicate that resources were capable of maintaining fishery production; but this may not be the case, since there is evidence that harvested fish sizes are smaller than in previous years and some important species are reported to have declined in number. Between 1996 and 2000 artisanal catches showed a decline of 15% from 58,500 to 49,900 tons, which is likely attributed to the late build-up of effort.

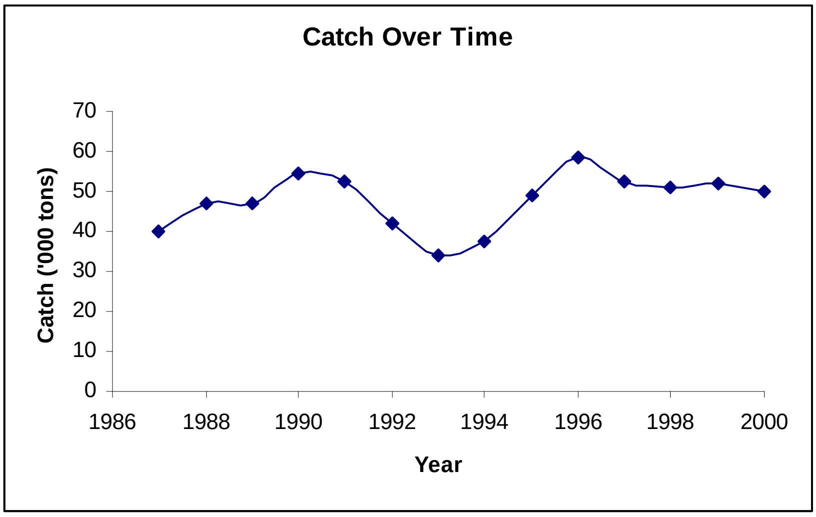

Fig. 4.2 Artisanal catches over time.

4.5 Price of Fish and Cost of Effort

The present study used the 2000 average fish price (T.Sh 800 per kg) as a constant price over the years. The unit cost of effort, however, was estimated assuming the fishery was at open access equilibrium in the year 2000 where the corresponding effort level of 5412 standard units was considered to be the open access effort, (E_{OAY}). Unit cost of effort, *c*, was therefore estimated to be T.Sh 6,560,160 per annum based on $E_{OAY} = \left(a - \frac{c}{p}\right) / b$ and was used constantly over the years.

Table 4.5 Economic Data

Economic parameter	Amount
Price per Kg	T.Sh 800
Cost per unit standard effort	T.Sh 7,307,658
Estimated discount rate (Based on the interest rate of Bank of Tanzania, 2000)	10%

CHAPTER 5. RESULTS

5.1 Estimated Total Standardized Effort and Corresponding CPUE

Standard effort units performed by each gear in a given year was found by the product of the estimated standardizing weight and the real effort value of the gear in that year, and were summed up for the various gear groups to yield the total standardized effort exerted per annum. Accordingly total standard CPUE was found based on the catch values in Table 4.4.

Table 5.1 Calculated total standardized effort and total standard CPUE for the fishery 1987-2000.

Year	Total Standardised Effort units	Total Standard CPUE (ton / unit std. Effort)
1987	2149	18.61
1988	2526	18.55
1989	2830	16.66
1990	3170	17.20
1991	3166	16.54
1992	2098	20.11
1993	1698	20.16
1994	1944	19.18
1995	3296	14.80
1996	3870	15.12
1997	4528	11.60
1998	4864	10.53
1999	4950	10.52
2000	5412	9.22

5.2 Trends in Total Standardized Effort

Figure 5.1 depicted that the total standardized fishing effort dropped down after1991 up to 1993, whereafter it has been increasing steadily.

5.3 Total Standard CPUE Trends

From the total standard catch per unit effort figure (Fig. 5.2), one can see that CPUE remained fairly stable during the late 1980’s and early 1990’s, where after it started dropping. A peak of CPUE was attained in 1993, which may be accounted for by the major reduction of fishing effort during the indicated period. This was, however, followed by subsequent drop of CPUE to as low as 9.22 in 2000 with further entry of efforts into the fishery. In other words, between 1993 and 2000 CPUE decreased by 55%. The decline may signal that the artisan fishing industry has been exploiting the coastal fishing grounds at the maximum and that decline in catch rates in the late 1990's may indicate overfishing. The way CPUE trends appear can be explained by the employment of increasingly higher effort levels and the increased use of fishing gears with reduced mesh size, which are indiscriminate in their catch.

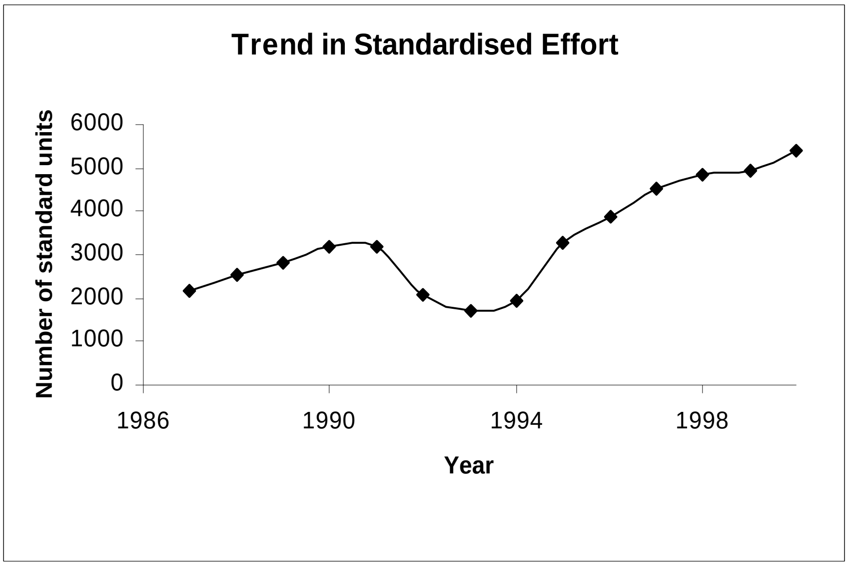

Fig. 5.1 Total standardized effort 1987-2000

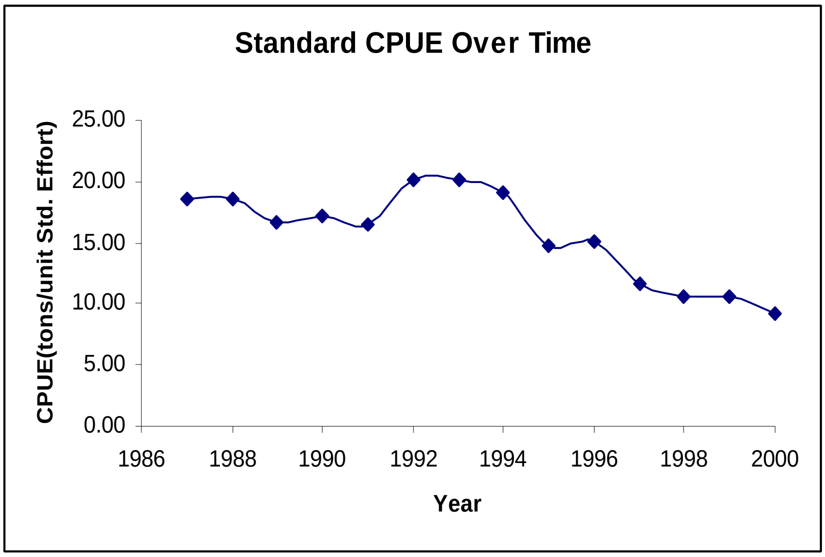

Fig. 5.2 Trend in Total Standard CPUE.

5.4 Yield - Effort Curve

The harvest function for the marine artisanal fishery based on equation (6), and by injecting parameter estimates from Table 4.2 was found to be:

$H(E) = 0.0261E - 0.00000313E^2$, where E = total standardized effort units from table 5.1.

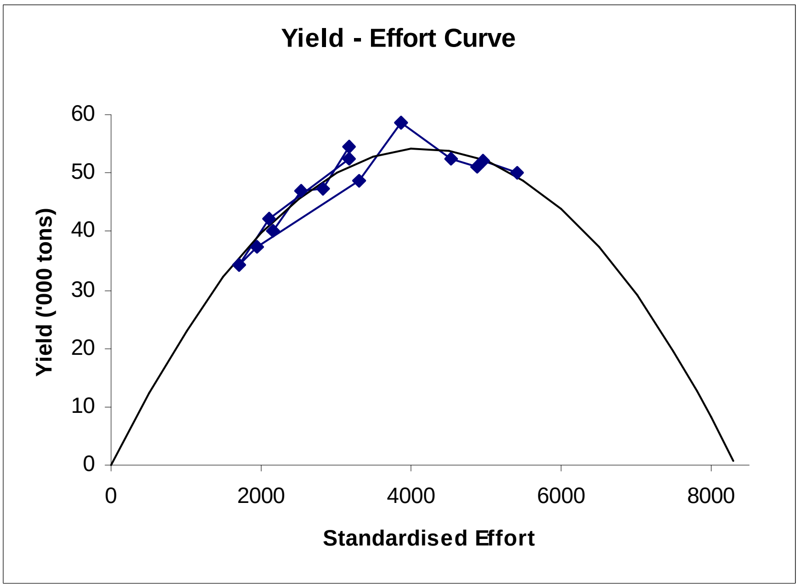

Fig 5.3 Gordon-Schaefer Harvest Curve for the fishery 1987-2000 based on equation (6) and catch data from Table 4.4.

5.5 Calculated MSY, MEY, OSY and OAY and Corresponding Effort Levels and Economic Rent

Table 5.2 Calculated effort, catch, costs, revenues and profits of the marine artisanal fishery of Tanzania based on the empirical model.

Model	Variable	Harvest Condition		
		MSY	MEY	OAY
Schaefer	Effort (stand.units)	4163	2706	5412
	Catch ('000 tons)	54.329	47.676	49.436
	Cost (Billion T.Sh)	30.42	19.775	39.549
	Revenue (Billion T.Sh)	43.463	38.141	39.549
	Profit (Billion T.Sh)	13.043	18.366	0

As indicated in Table 5.2, MSY was at 54,329 metric tons valued at T.Sh 43.463 billion and produced at effort value of 4163 standard units. When these estimated values were compared with the recorded catch and effort values in Table 5.2, the MSY level occurred back in mid 90's. The MEY, on the other hand, was at 47,676 metric tons valued at T.Sh 38.141 billion and obtained at effort value of 2706 standard units. Comparing these with the actual catch and effort figures, MEY was attained back in the late 80's. The OAY was at 49,436 metric tons valued at T.Sh 39.549 billion and produced at effort level of 5412 standard units. Figures in Table 4.2 indicate that this level was reached in late 90's.

Such biological parameters as *K* and *r* were not readily available for the present study. In order to come up with estimates of optimal biomass, optimal catch and effort levels; *K* was assumed to range between 50,000 and 500,000 tons where a change in *K* also implies changes in corresponding *q* and *r* as indicated in Table 5.3 below.

Table 5.3 Optimal Biomass, Catch and Effort levels in response to changes in the biological parameters *K*, *q* and *r*.

K	q	r	X*	OSY	E_{OSY}	TR (Bil T.Sh)	TC (Bil T.Sh)	Profit (Bil T.Sh)
50000	0.000522	4.346	32391.85	49580	2932	39.664	21.426	18.238
75000	0.000348	2.898	48354.76	49777	2958	39.822	21.615	18.207
100000	0.000261	2.173	64165.09	49969	2983	39.975	21.802	18.173
125000	0.000209	1.739	79824.90	50155	3009	40.124	21.988	18.136
150000	0.000174	1.449	95336.27	50335	3034	40.268	22.172	18.096
175000	0.000149	1.242	110701.28	50509	3059	40.408	22.354	18.054
200000	0.000131	1.087	125921.98	50679	3084	40.543	22.534	18.008
225000	0.000116	0.966	141000.46	50842	3108	40.674	22.713	17.961
250000	0.000104	0.869	155938.77	51001	3132	40.801	22.891	17.910
275000	9.49E-05	0.790	170738.98	51154	3156	40.924	23.066	17.857
300000	8.7E-05	0.724	185403.16	51303	3180	41.042	23.240	17.802
325000	8.03E-05	0.669	199933.34	51446	3204	41.157	23.412	17.745
350000	7.46E-05	0.621	214331.59	51585	3227	41.268	23.583	17.685
375000	6.96E-05	0.580	228599.94	51719	3250	41.375	23.752	17.623
400000	6.53E-05	0.543	242740.42	51848	3273	41.479	23.919	17.559
425000	6.14E-05	0.511	256755.07	51973	3296	41.578	24.085	17.494
450000	5.8E-05	0.483	270645.88	52093	3318	41.675	24.249	17.426
475000	5.5E-05	0.458	284414.88	52209	3340	41.767	24.411	17.357
500000	5.22E-05	0.435	298064.05	52321	3362	41.857	24.572	17.285

As it can be seen from the above table, optimal stock level (X^*) was very sensitive and had almost the same percentage change in response to a change in *K*. Where as the optimal sustainable yield and effort levels were robust and more or less consistent to changes in the biological parameter values. Considering *r* value to lie between 1 and 2 for the tropical stock under study; OSY and its effort level were found to be in the vicinity of 50,000 tons and 3000 standard units, respectively. Comparing these with the actual situation, OSY has been attained back in early 1990's.

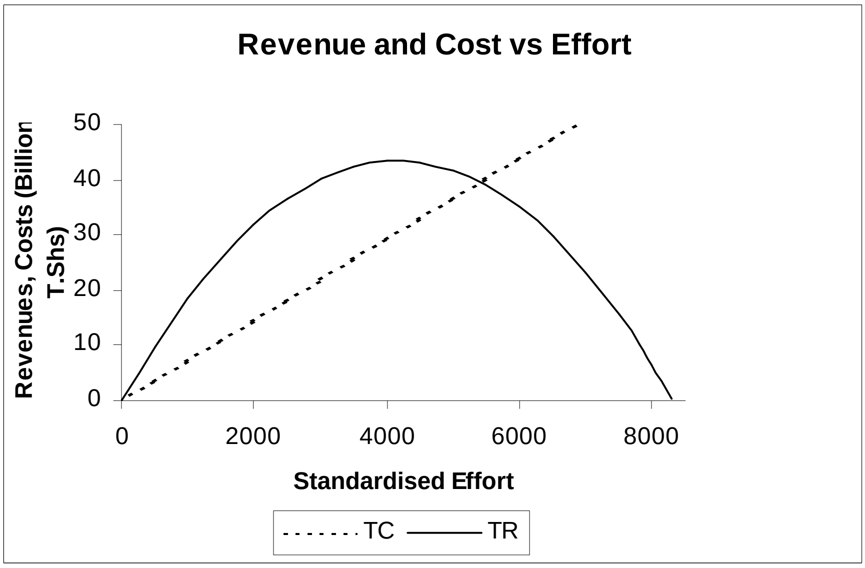

Fig. 5.4 Revenue and Cost as function of standardized effort

The computed total revenues, total costs and economic rents using the GS model are also provided in Table 5.2 and Table 5.3, and the revenue and cost curves are depicted in figure 5.4. The economic rent generated when the fishery is operated at MSY level was T.Sh 13.043 billion per year. On the other hand, if operated at MEY and OSY, the annual economic rent was T.Sh 18.366 billion and T. Sh 18.0 billion, respectively.

CHAPTER 6. DISCUSSION

6.1 Is There Overfishing in Tanzania's Marine Waters

Detailed scientific data on stock levels, regeneration and catch are required to examine biological overfishing of fish stocks (Israel and Banzon, 2000). Such valuable information, however, is not available for the present study. Less costly methods such as observing certain indicators like catch size over time, catch per unit of effort, price changes, changes in market supplies and changes in percentage composition of species or size over time can be good references to address overfishing (Pauly, 1987). For example, a declining CPUE, a tendency to catch more small-sized individuals, a fall in fish catches, a change in catch composition and price rise or drop are indicators of overfishing. Yet, no single factor can be sufficient to ascertain the needed information since each of the indicators has its own shortcomings. Therefore, a combination of all or at least some of these indicators is important to come up with a reasonable conclusion.

Catches in Tanzanian Marine waters have declined by about 15 % since mid 1990's, and CPUE drastically reduced in the late 1990's. This can be explained due to the effort pressure that is exerted in small fish, which does not contribute a lot in terms of total weight in yield. From discussions with fishery officers, it was learned that the fish caught now are smaller in size (15 cm average standard length) compared to what the fishermen used to get in the past two decades ago (Y. Mgawe and co., pers. comm.). While the relative catch contribution of small pelagics is more or less consistent, there has been a recent decline of certain commercial reef fishes that are high in the food chain such as snapper, grouper, emperor and others as more and more effort is being exerted on them at least by handline and longline users (Anon., 2001a). Fish prices have been significantly rising with the declining market supplies relative to the increase in population number, and this may suggest that the stock is becoming scarce. Besides, by-catches have never been reported being discarded by fishers. Based on the aforementioned indicators, therefore it is evident that there was overfishing of fishery resources.

According to the 2001 Frame Survey, fishermen in different fishing villages of Rufiji, Bagamoyo, Pangani, Mafia and Kunduchi believe that there are still abundant fish stocks beyond the inshore waters. But because of technical constraints they have to restrict themselves to the inshore waters, which are believed to be overexploited (Jiddawi, 2001). Therefore, the overfishing seems to be localized, restricted to the inshore waters and can be seen to be a consequence of the lack of capital and skills on the part of fishermen where the majority who cannot afford bigger or motorized vessels have to concentrate in the coastal waters. Because of the high competition for the limited coastal fish resources, many fishermen resorted to beach seining, small-meshed gillnets and other unsustainable methods like dynamites. Linden and Lundin (1996) also noted that in view of the high exploitation rate of the inshore areas, the scope for increased yield from their capture fisheries is inconceivable and future increases in catch must therefore come from areas outside the reefs.

6.2 Major Factors Accounting for the Overfishing

The present overfishing in Tanzania's marine fisheries can generally be explained by such major factors as:

- *The employment of increasingly higher effort levels*: In line with the increasing coastal population; fishing gears, vessels and fishermen have been expanding in the coastal waters since majority of the fishermen are poor and use low quality fishing gear and vessels, which lack mechanization to exploit the offshore resources. Marginal population particularly among the youths has been pushed into the fisheries sector due to absence of alternative employment. The increase in fishing gears especially ring nets, which require large number of crews; longlines, handlines and gillnets has been absorbing more and more fisherfolks. The ever-increasing domestic demand for sardines and anchovies resulted in the expansion of ring nets since mid 90's. In the aim of targeting the relatively high priced demersal fish such as snapper, emperor, grouper and the likes, and pelagic species like tuna, longlines have been showing a dramatic increase since mid 90's. Since gears like handlines have low capital costs, cost of entrance has been low. These all contributed to effort build-up, which caused reduction in the size of the fish stock and the consequent decline in catch per unit of effort. The perception of fishers interviewed on landing beaches like Dar es Salaam and Bagamoyo also indicated that their current fishing was less successful. They asserted that decreases in their fish harvest were due to increases in the number of fishers and fishing units.

- *The increased use of fishing gears with reduced mesh size*: The use of small-mesh nets mainly seine nets despite their official ban, and gillnets (smaller than the recommended minimum mesh size of 5 cm) in shallow water areas by large number of fishermen has caused considerable damage by the indiscriminate catching of all fishes, large and small, in the area irrespective of their value. This might have led to local overfishing of specific stocks. These nets further destroy coral reefs and sea grasses when they are dragged on the bottom and when they get entangled.

Other factors that aggravated reduction in stock sizes which in turn negatively affect catches include:

- *Uncontrolled cutting of mangroves and the increased use of dynamite*: There is an increasing mangrove cutting for timber, poles, fuel wood, charcoal and local medicine particularly in Pangani, Rufiji and Bagamoyo (Mochii et al., 1998). Uncontrolled cutting of mangroves that serve as nursery grounds for variety of fish, shellfish and prawns leads to reduction of the stock. In deed, dynamite fishing has destroyed many coral reefs that are important breeding grounds. It has been observed that coral reefs and mangrove forests increase the carrying capacity of the marine environment. Hence their destruction reduces the capacity of the environment to accommodate larger stocks, and less stock implies less catch.

- *The intrusion of trawlers:* The fact that trawling for prawns takes place in the same inshore waters that are also used by artisan fishermen has been resulted in the loss of target species of artisanal fisher folks as by-catches by industrial fleets before they grow larger.

6.3 Sustainability, Efficiency and Optimality

To establish the ecological sustainability of current fish harvesting practices, the estimated maximum sustainable yield and the corresponding effort levels were compared with the actual catch and effort figures. Obviously a fishery is not sustainable if total catch exceeds the MSY level. Artisanal sector of the marine fisheries has since 1997 moved into a situation of biological overfishing. Economic overfishing, however, started several years before.

From an economic point of view MSY doesn't imply efficient harvesting, relating efficiency to maximizing the net benefit from the use of economic resources, i.e. maximizing the resource rent (Hartwick and Olewiler, 1998). Resource rent is maximized at lower level of effort, the MEY level. The MEY point yet depends on prices and costs, and therefore is not constant overtime, rather it varies as price of fish and inputs change. The MEY and its corresponding effort level were calculated as 47,676 metric tons and 2706 standard units respectively. Comparing these values with the actual catch and effort figures, the atisanal fishery sustained economic overfishing during 1989-1991 and 1995-2000.

Although the equilibrium estimators MSY and MEY are useful benchmarks as reference points in the bioeconomic analysis of fisheries, their static nature may diminish their reliability as appropriate management tools. Optimal sustainable yield, which takes into account the price of time (d), however, is a better dynamic reference point. Indeed, a fishery will be economically efficient if it maximizes the net present value of catches. For the study, OSY and its effort were estimated to be about 50,000 tons and 3000 standard units. When compared to the actual situation, there had been excess effort during 1990 - 91 and 1995 - 2000.

6.4 Required Reduction of Effort

The present fishing effort has been certainly wasteful as it caused unnecessary costs. That is, some factors of production (both capital and labour) have been wasting and contributing nothing to the fishery. Therefore, in order to attain sustainable, efficient or optimal levels, the fishing effort has to be lowered from the level of 5412 standard units in 2000 (Table 5.2). Percentage-wise, fishing effort will have to decrease by about 23 % to attain MSY. To get the MEY and OSY level, on the other hand, it will have to be reduced by 50% and 45%, respectively.

6.5 Employment Impacts of Effort Reduction

A reduction in fishing effort to attain MSY, OSY or MEY will raise productivity of the marine fisheries. However, it will also result in the unemployment of fishermen who will be eased out fisheries. This is a major problem in countries like Tanzania where the rest of the economy may not have enough room to accommodate the displaced fishermen, or when there is no alternative employment outside the fishing sector. In view of the social and equity considerations people need to be accommodated with in the fishing sector though they do not contribute to the value produced. However, withdrawing fishing would mean reduction in cost as well as increase in the resource rent, which could be used to compensate the unemployed fishing people. Further, diversification of skills could be done to make them more suitable for non-fishing sector.

6.6 Limitations of the Study

- It must be pointed out that there was data error and great concern as to the reliability and accuracy of the data used.
- The exploitation levels and economic rents generated by the study depend to a large extent on the price of fish and cost of effort assumed in the analysis. A decreased price of fish or an increased cost of effort, for instance, may substantially reduce the value of the estimated economic rent that can be generated from the fishery, and vice versa. In the future, a study that will use more accurate and variable fish and effort prices will be useful.
- The GS model only considers fishing effort and stock biomass as factors influencing fish catch. Other determinants of fish catch such as annual changes in weather were excluded. The extent by which these and other factors influence fishing has not been investigated here and should be considered in a future study.

CHAPTER 7. SUMMARY AND POLICY RECOMMENDATIONS

The study evaluated the artisanal sector of Tanzania's marine fisheries for the period of 1987 – 2000 and findings revealed that effort has already reached and surpassed the maximum sustainable level, i.e. there is overfishing problem and that the fishery has never been managed for economic efficiency. The potential resource rent at MEY was estimated to be T.Sh 18.366 billion per annum, but all economic rent from this fishery has been continued to be dissipated.

The open access fishery has been maintained in order to keep the people with in the fishery in the absence of employment opportunities outside the fishery sector. In view of this there is need to undertake regulatory measures to preserve the stock which implies the reallocation of resources from existing open access to a controlled system designed to maximise social welfare of the fisherfolks. Hence policy action in such small-scale fishery may be directed in maximising optimal yield (OSY), which recognises such multiple objectives as social, biological and economic benefits.

While effort reduction should be a primary goal in the marine fisheries, the impacts of such reduction in terms of equity is important. That is, there should be a strong balance between efficiency and equity objectives. An isolated policy to simply lower effort will likely be more difficult to implement because artisanal fishing is largely subsistence in nature and a matter of survival for fishermen community (Waters, 1991). Forcing them out of their livelihood with out an acceptable alternative employment program will be viewed by many as inequitable and morally unacceptable. Hence, a retaining and employment program may be necessary. A potential option is for the national government and private sector to pool their resources and organize such programs as promotion of eco-tourism and dispersion of industrial development into the rural coastal areas where the more fishermen are employed in these establishments, the less will be the fishing effort.

Policies that recognize and incorporate indigenous fishing communities will most likely be successful if sufficient authority and power are delegated to the local level (Charles, 2001). These will help the local communities acquire the direct responsibility for management and protection of the fishery and other marine resources. To that end, a great emphasis should be placed on educating local fishing communities on the effects of unsustainable fishing and the benefits of managed fishery resources. In this case, the Mafia marine park (community-based conservation approach), where the local people are integrated into the management system and their indigenous knowledge of fishes and other marine resources is utilized in designing management, is a good example. Apart from these, the effective enforcement of the existing fishery regulations must be pursued.

Generally, management measures need to be imposed mainly for two reasons: to preserve the fish stock from depletion and to protect the economic position of the fishing society. Finally, in order to shed more light on the current traditional exploitation, qualitative and quantitative studies have to be conducted at smaller scales to record more detailed information. In addition, better monitoring of fish landings is necessary for the formulation of viable management. Thorough understanding of the exploitation patterns by regular monitoring of resources provides suitable baseline information which is a vital requirement for rational use, especially at this time when there is a growing gap between population increase and the availability of food (fish supply).

8. REFERENCES

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