An Economic Analysis To Sustainable Fisheries Management[1]

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Abstract. The coastal zone is a dynamic area surrounding the interface between land and sea. The coastal area and its resources offer great benefits and opportunities for human use. Most coastal activities in Tanzania rely on the natural resources that the coast offers (fishing, forestry, agriculture, tourism, mining, salt production mariculture etc). Therefore the condition of the coastal ecosystem and social well being are closely linked. The challenge is to maintain and improve the resources base on which those activities are dependent, while developing new economic opportunities in a way that benefits the people of the coast and the nation as a whole. A major constraint is the inadequate institution and legal framework for coastal management. Economics is about efficient allocation of resources. In normal cases market forces provide efficient allocation of resources. In fisheries, however, market forces alone can not produce an efficient allocation. And as it has been evident in this paper there is already overfishing in most of the offshore waters where majority of artisan fishernen concentrate. Thus calling for policy intervention to rescue the stock from depletion. This should include licencing, seasonal closure; finding alternative economic activities to fishermen, and community based conservation approach can as well be instituted.

Keywords: Artisan Fisheries, Efficiency, Bioeconomic model, Maximum Sustainable Yield, Maximum Economic Yield, Open Access Equilbrium.

1.0 INTRODUCTION

Tanzania coastal waters that consist of Zanzibar and Mafia channels and a narrow continental shelf are very important to the coastal population. Unsurprisingly therefore, artisan fishing is the main economic activity of the majority of the people living along the coastal of Tanzania stretching from Mtwara in the south to Tanga in the north. At least 90 percent of the total marine catch comes from artisan fishing activities. It provides an important source of income, food, and employment opportunities, directly as well as indirectly. Today commercial fishing along the coast also contributes significantly to employment opportunities and foreign exchange earnings.

Fishing gear includes gill nets, seine nets, baskets, traps, hand-lines, long-lines, fence traps, spears, and trawlers. Trawl nets constitute the industrial fishing methods and are limited to coastal prawn trawling. Some of the fishing gear poses a threat to the resources, which include beach seine nets, which catch juvenile fish and destroy the habitat due to the dragging force. Another destructive fishing method is dynamite, which is practiced illegally. This method indiscriminately kills all living organisms and they breeding ground and destroying coral reefs.

The sustainable harvesting of the marine resource in general requires that the catch rate should not exceed the growth rate of fish. That is where we have Maximum Sustainable Yield (MSY), which is the biological optimum. Beyond such a point harvesting is unsustainable, because then overfishing occurs. Another aspect that needs to be considered in the harvesting of marine resources is the maximization of the economic rent. That refers to attaining the economic equilibrium, which is referred to as the Maximum Economic Yield (MEY), which is the main focus of this paper.

Fishermen like any other economic agent are driven by the profit maximization objective at least in the short run. With this there are all reasons to believe that fishermen and fishing efforts will increase as fish catch command high prices in the market. Their fishing efforts (both gear and fishing hours) will increase because of the high demand that exists for both fish and fish products. The high demand is reflected in high relative prices. The overall picture of fish prices is that they have risen significantly faster than the prices of other goods in Tanzania. This faster increase in fish prices other things being equal means high profit, hence attracting more efforts. Thus putting the danger of extinction of the stock. As mentioned earlier, overfishing is judged on the basis of decline in CPUE, change in catch composition and increasing catch of juveniles. In the long run therefore as

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will be argued in this paper, overfishing and rent dissipation are the likely outcomes. Thus without proper management the danger that resources can reach extinction levels is high. Thus where there are economic incentives to fish more, regulatory mechanisms are needed to ensure sustainability in the long run. The underlying idea is that the prevailing fishing regime should be economically efficient and ecologically sustainable.

This paper examines a number of theoretical economic concepts that are central to the management of the exploitation of the fisheries resources in a manner that ensures sustainability in economic terms. It specifically focuses on the applicability of these concepts in the Tanzania marine fisheries.

1.1 Objective of the Study.

The main objective of this study was to examine the number of theoretical economic concepts that are central to the optimal exploitation of fishery resources, and focuses especially on their applicability in the Tanzania marine waters. The study intends to base on empirical investigations that will provide insight into the following two critical questions: (I) Are the present fish harvesting levels in marine waters sustainable? (ii) If fish harvesting is at levels that are unsustainable, what mitigative measures could be instituted to ensure sustainability in the long run?

The other specific objectives aims at identifying and establishing the main causes influencing over-exploitation, the disturbance of the marine ecology and the use of destructive fishing methods.

1.2 Significance Of The Study

The importance of marine 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 relatively cheap protein to the population. The findings of this study will fill the existing gap of empirical studies that focus on the economic analysis of the sustainable use of marine resources in Tanzania. The information is also expected to assist policy-makers and interested parties to make informed decisions about the economic 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. The knowledge will further facilitate the designing of appropriate mitigative measures.

The paper is organized as follows; in the next section the economics of fisheries.Section Three presents the results. Section four presents recommendations and conclusions. And Appendix A presents the Methodology of the study.

2.0 THE ECONOMICS OF FISHERIES EXPLOITATION

The economic analysis of extinction was initially developed in the context of marine resources, providing the earliest examples of endangered modern species. The pacific fur seals almost reached extinction in the late nineteenth century due to overexploitation. The blue whale experienced a severe decline during the same period (Ruddle, 1992).

The study of over-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, 1976). Bioeconomic models are based on the work of Gordon (1954) and Schaefer (1957) who developed what has come to be known as the basic bioeconomic model of fisheries management. The questions addressed in these models concern the characteristics of a resource and resource management systems that rendered them incompatible, so that the resource was incapable of sustaining the systematic pressures placed upon it by humans.

The limitations of the model are that it includes only a single species and it ignores the age structure of the fish population. The model therefore is limited in its usefulness as an operational tool in managing tropical fisheries that reach commercial size at varying ages. Despite these shortfalls, the model provides a useful framework for understanding the basic economic principles involved in fisheries management.

The model developed assumes that the annual growth of fish is related to the level of stock, by an inverted U-shaped function. Given the constraint of the carrying capacity of the environment, the model postulates that growth is large when stocks are small, and as the stock increases growth increases at a decreasing rate until it reaches a maximum and eventually falls (Tinteberg, 1996). Growth therefore reaches a maximum at intermediate stock sizes. Annual catches can be sustained indefinitely as long as the catch equals annual growth. This is referred to as Maximum Sustained Yield (MSY)[3].

[3] MSY in this case refers to the catch level, which if maintained perpetually would produce the largest annual net

2. 1 The Concept of Overfishing

Biological overfishing occurs if the same or less fish can be caught using fewer efforts. This happens when effort exceeds the MSY point. This is illustrated in Figure 2.1. At effort level E_1 Effort exceeds the MSY effort level (E_{MSY}) and yields the catch of B_1. However, the same catch could be obtained using less effort that is at E_2. At E_2 the stock is large and therefore less effort is needed to catch B_1 tons of fish. The implication of this is that the catch per unit effort (CPUE) is high at E_2 than at E_1, implying that with overfishing, greater effort is needed to be able to extract the same quantity (or less) than what was obtained previously.

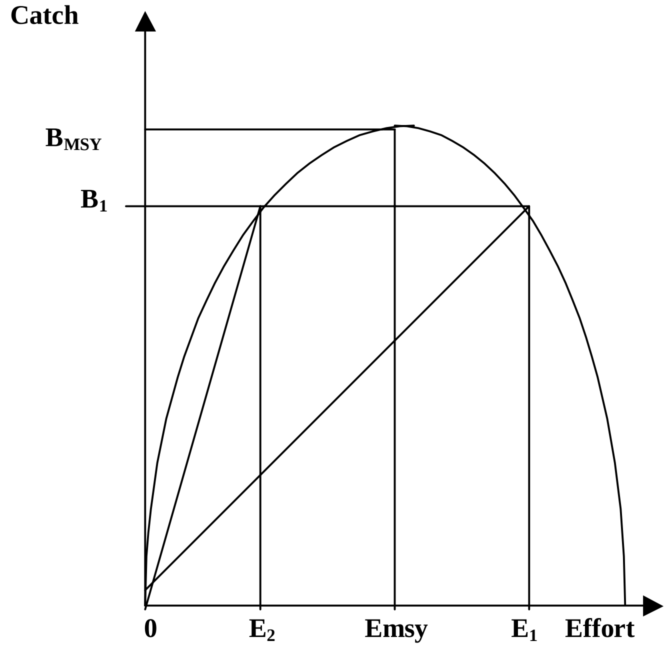
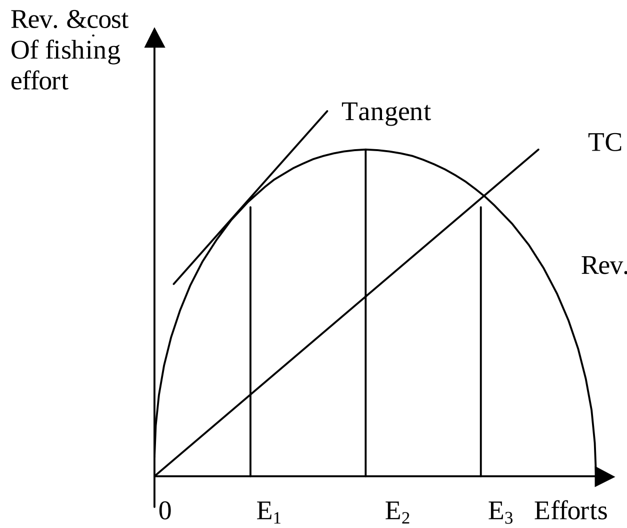


Figure 2.1 Catch-Effort Curve

2. 1.1 Efficiency vis-à-vis MSY

From an economic point of view, MSY does not imply the efficient harvesting of resources. Efficiency is concerned with maximising the net benefit from the use of economic resources, i.e., maximising the resource rent. To attain efficiency in the economic sense, we need to take into account the costs of fishing and revenues from selling the fish catch. The difference between the revenues generated and the cost of fishing is the profit earned by the fishery.

The concept of MSY implies that catches, population; (catch), effort level and net benefits remain constant over time. With this the catch-effort curve (Figure 2.1) can be converted to define revenues and costs as a function of fishing effort measured in the number of vessels per year. This is illustrated in Figure 2.2. The slope of the cost line measures per unit cost of fishing effort. From Figure 2.2, as sustained levels of effort become increased, a point is eventually reached (E_2) beyond which the sustainable catch as well as revenues are reduced. That point corresponds to the MSY point in Figure 2.1 (Clark and Monro, 1975).



Note. E1 Equilibrium E2 Biological Equilibrium
E3 Open Access Equilibrium
Rev. =Revenue

Figure 2.2 Efficient Sustainable Yield

The net benefit is presented in the diagram as the difference between benefits and costs. The efficiency level of effort is E_1. At that point, the vertical distance between benefits and costs is maximized. It is therefore an efficient level of effort because it is where marginal revenue (MR) equals marginal cost (MC).

Levels of effort higher than E_1 are inefficient because the additional cost associated with them exceeds the value of the fish catch (Swamson, 1991). Similarly the use of effort below E_1 is equally inefficient since the additional cost will be greater than the additional revenue generated. E_2 (MSY) is not efficient since the MR at that point is zero while the MC is positive, implying therefore that the efficient level of effort is less than that necessary to harvest the MSY. Point E_1 is referred to as Maximum Economic Yield (MEY).

This implies therefore that if the industry were privately owned, efforts would not have being expanded beyond MEY (the economic equilibrium point). The point is both a social and private optimum. Marginal revenue measures society's willingness to-pay (WTP) for fish and marginal cost measures the opportunity costs of the labor and capital used in fishing. *This suggests that the application*

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benefits.

of fishing effort beyond the MEY point result in fish being caught at a cost greater than their value to society.

As discussed earlier the fishing industry is seldom privately owned but typically an open access resource (open to all with the means to own and use fishing vessels and gear). Thus as long as there are positive profits that can be earned from the resource as depicted in Figure 2.2, at MEY and MSY, more fisher folk will continue putting more effort into the resource until the profit is eliminated, which is beyond the MSY point i.e. when the open access equilibrium (E_3) point is attained. At E_3, the total cost of fishing effort is equal to the total revenue, but that is a position where there is both biological and economic overfishing. This need not always be the case, particularly when the unit cost of fishing is high (Clack 1973). If the unit cost is relatively high E_3 can lie between E_1 and E_2. When open access does lead to biological overfishing, the fishing industry can collapse altogether and fish stock can be drawn into extinction (Schaefer ibid.). Analysis along this line has been carried out by many other economists, including Smith (1969), Bell (1972), Hannesson (1989), and Bagachwa and Maliyamkono (1994), Vincent *et al*, (1996).

From this, if then, we have human agent seeking to maximize the value of the resources and considering the case when the resources are privately owned. The problem of the sole owner can be stated formally as

Maximize $\int [PYt - C(Yt,Xt)e^{rt}dt$……………….(1)

Subject to $dX/dt = g(X) - Yt$………………….(2)

where P is the price of the resources (taken by the owner), C(Y,X) is the cost of harvesting, Yt is the flow of the catch at time t; Xt is the remaining stock.
The Hamilitonian for the problem is:

$H = PYt - C(Yt,Xt) + \rho t[g(X) - Yt]$……………..(3)

where ρt is the co-state variable attached to the constraint. Differentiating with respect to the control variable Yt and setting the results equals to zero we obtain:

$\delta H/\delta Yt = P- \delta C/\delta Yt - \rho t = 0$…………………..(4)

The expression describing the rate of change of the royalty ρt, is complicated by the presence of the growth function ρt, evolves according to:

$d\rho t/dt = r\rho t - \delta H/\delta Xt$

$= r\rho t + \delta C/\delta Xt - \rho t\delta g/\delta Xt$………………(5)

where $\rho t\delta g/\delta Xt$ is the values of the extra growth that results by holding a unit of the resources stock. And $\delta C/\delta X \leq 0$; that's the decline in stock the cost per unit effort increases. Thus the stock effect.
Rearranging the optimality condition in terms of the incentive to conserve and incentive to develop:

$dP/dt = r\rho + \delta C/\delta X - \rho g'(X)$

$r\rho = dP/dt - \delta C/\delta X + \rho g'(X)$……………….(5')

Where the left hands side is the incentive to harvest now than tomorrow. It is clear from this that a high discount rates r, which is the value of harvested stocks, will provide a strong incentive to fish now than wait. They are therefore likely to lead to over-exploitation of fishery resources. The right hand side is the incentive to conserve and harvest in the future. The first term in the RHS is the capital gain, the second term is the stock effect; the cost saved and the last term is the value of added growth. And (5') suggest that a sole owner will be indifferent of whether to proceed fishing or not since the incentive to conserve is equal to incentive to harvest. On the bases of the above condition we can be able to analyze under what circumstances is MSY said to be economically best.
To have this we need to pose the following strong assumption.

1. assuming a steady state hold, such that; $dP/dt = 0$.
2. no stock effect, ($\delta C/\delta X = 0$) that the second term is zero that is there is no increase in cost caused by stock depletion.
3. no discounting; $r = 0$

With these assumptions at hand equation (5') collapse to zero, such that $dg/dX = 0$. But $dg/dX = 0$ only at $X = Xm$ which is the MSY stock level (Fig. 1.1 and 2). In this special case the MSY coincides with the economic optimum. It makes sense to pick the stock that gives the highest yield in perpetuity.

Consider the case which arises when $r = 0$ and $\delta C/\delta X = 0$. From equation (5'); $dg/dX - r > 0$. Implying that the equilibrium is at the left of MSY, in other words the steady state is below that corresponding to the sustainable level. The stock is optimal drawn down because future losses are discounted and there is no cost penalty for temporarily increasing the harvest. Economist presumably has this mind when criticizing MSY. On the other hand when $\boldsymbol{\delta C/\delta X < 0}$ and $\boldsymbol{r > 0}$**;** from equation (5') we have $\boldsymbol{dg/dX - r + (\delta C/\delta X)/\rho \leq 0}$ or $\boldsymbol{dg/dX - r + (\delta C/\delta X)/\rho \geq 0}$ as **r can be greater or less than** $\boldsymbol{[(\delta C/\delta Xt)/\rho t]}$**.** Thus in the general case it is not possible to say whether the optimal steady state stock is to the left or to the right of MSY stock.

Extinction is more likely when the resources is like many fisheries, a common property. The basic idea is that when firms can enter freely and no cooperative agreements have been reached, each ignores the user cost, (ρ) of extracting

a unit today, as well as any diseconomies of crowding, (the different between marginal and average costs, δC/δYt and C/Yt respectively in our model). All profits from the stock is competed away, and the industry equilibrium occurs when Pyt - C = 0 as shown in the Figure below. This is the situation when there is no incentive to exit or enter into the fishery industry.
The zero profit condition is graphed as linear relationship. C = PYt in figure 2.3 below.

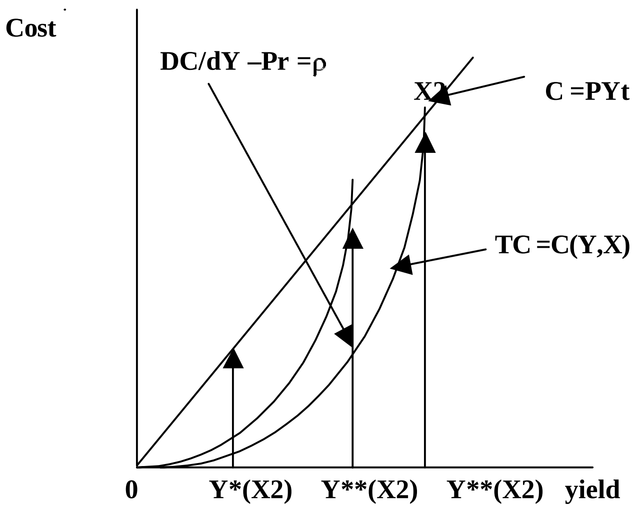

Figure 2.3: Economic Optimal of Harvesting Level

The catch locus is found by taking the intersection of total revenue, PYt and total cost, C(Y,X), for each stock. The intersection of the straight line PYt with the cost curve, C(Y,X) for a given stock lies to the right of the point at which δC/δYt = P - ρt. It can be seen that when the stock is depleted to zero the cost is very high relative to a positive stock. As illustrated in Fig.2.3 the common property regime leads to a stock which correspond to yield level Y*(X2) which is less than the stock level with private property equilibrium corresponding to (i.e. Y**(X2).

To attain optimum we can introduce per unit tax on the resource. For example. a tax per ton of fish landed. From equation 4 we know that, in an optimal regime, price (P) equals marginal extra cost plus royalty. In the unrestricted CPR, price equals AC. A two - part tax is then called for, with one part equal to the royalty, ρt and the other equals to the different between MC and AC, δC/δYt - C/Yt assuring those users to take account of the future losses and current crowding respectively.

3.0 RESULTS

3.1 Is There Overfishing In Tanzania's Marine Waters?

Overexploitation of fish stock can be estimated from detailed scientific data on stock levels, regeneration and catch. However, this sort of information is not always available and less costly methods such as observing certain indicators such as catch size over time, changes in the relative share of juveniles over-time, catch per unit effort, price changes, or changes in market supplies, changes in the percentage composition of species over time in total catch etc. For example if there is a tendency to catch more juvenile fish this is an indication that there is overfishing. A declining CPUE also indicates overfishing. A rise in the price of catch or declining market supplies suggests that the resource is becoming scarce. However, no single indicator can suffice to provide the needed information as each of the indicators has it is own shortcomings. For example where we have market imperfections or controlled prices, an increase in price does not necessarily imply that resources are getting scarce. Therefore a combination of all or at least some of these is important to arrive at a reasonable conclusion.

Based on the above-mentioned indicators, it is evident that there was overexploitation of some fish resources. The overfishing seems to be localized, restricted to particular areas. This stem from the fact that the fishermen interviewed in different fishing villages of Rufiji, Bagamoyo, Pangani, Mafia and Kunduchi believe that there are still abundant fish stocks in the deep sea, but because of technical constraints they have to restrict themselves to inshore waters, which are believed to be overexploited. The overfishing evident in particular places can be seen to be a consequence of the lack of capital and skills on the part of fishermen. Thus those who can not afford bigger and motorized vessels have to resort to beach seining and other unsustainable fishing gears. However, from discussions it was revealed that the fish catches are small now and the fish caught are smaller in size compared to what they used to get in the past two or three decades ago, a clear indication of overfishing.

- **Trends in catch**

Trends in the marine fish catch in Tanzania have been characterized by fluctuations since 1970. The annual fish catch has fluctuated from 39,810 tons in 1980 to 54,527 tons in 1990 for the mainland. At the same time the number of fishing vessels, has demonstrated a tendency to fluctuate between 1980 - 1987. The largest number was registered in 1991 totaling 4,402 and the lowest 3232 in 1994. However, the number of fisher folk increased considerably for example. from 7,596 in 1980 to 15,027 in 1994. As a result of this, catch per fishermen registered a declining trend from the largest in 1980 (4.866 tons) to as lower as 2.441 tons in 1993. Also the catch per vessel declined from 14.476 tons in 1983 to 11.350 tons in 1993. Put together this signifies declining productivity, implying that the resources is becoming scarce.

This trends in Tanzania's artisans and industrial fishing industry in terms of fish landings and fishing effort (fishermen, canoes and trawlers) for a period of ten years (1981-1991). Between 1984 and 1990, there was an increase of 37% in fish landings by artisan fishers from 39,810 tons to 54,527 tons an average increase of 6.2% per annum. This may have been the result of the rise in fishing effort as during the same period the number of fishers increased from 13,783 to 16,178 or by 17.4%; an average annual increase of 2.9%. Similarly, artisans fishing vessels (canoe, dhows, and boats) also increased by 22.4% or 3.7% per year over the 6-year period.

Based on the catch per unit effort (CPUE), statistics suggest that there has been a decline in the total catch over the years. In 1988, for example, the total catch was 49,383 tons from all the coastal areas and the catch in 1995 was only 39,073 tons. This suggests a fall by 20% in 8 years. At the same time the number of fishermen and fishing vessels increased from 9,495 and 2,382 in 1983 to 15,349 and 32,124 in 1995 respectively. However, there were fluctuation trends in both catch and effort within the period. The CPUE therefore showed a declining trend. Species composition also showed a declining trend. Table 3.1 confirms as the catch rates in terms of catch per fisher and catch per artisans fishing vessels also increased from 3.2 to 3.4 tons per fisher per year and 11.2 to 12.5 tons per vessel per year respectively.

Catch /Fisher	Year	Catch /vessel	Year	Catch /Fisher	Catch/ vessel
3.6	**1983**	14.5	**1990**	3.4	12.5
3.2	**1984**	11.2	**1991**	3.2	11.9
3.7	**1985**	14.1	**1992**	2.8	12.0
3.6	**1986**	12.2	**1993**	2.1	10.6
3.1	**1987**	10.8	**1994**	2.5	11.5
3.4	**1988**	10.4	**1995**	2.7	12.5
3.2	**1989**	11.4	**1996**	2.3	10.6

Table 3.1 The Trend in Catch Rates (Catch per Fisher and Catch per Vessels) of Artisan Fishery 1993-1996

Between 1990 and 1994, artisan fish landings decreased by 32% from 54,527 tons to only 37,284 tons; an average annual fall of 6.3%. Similarly, catch rates also decreased from 3.4 tons per fisherman in 1990 to 2.5 tons per fisherman in 1994 or 12.5 tons per vessel in 1990 to 9.5 tons per vessel in 1994. In the period between 1994 –1996 the catch per fishermen and catch per vessel declined to 2.3 tons and 10.6 tons respectively. The decline may signal that the artisan fishing industry is exploiting the coastal fishing grounds at the maximum and that the decline in catches and catch rates since 1990 may indicate over-fishing. The way CPUE trends appear suggest that the efforts were not changing in a uniform pattern over time. This trend can be explained by four major factors:

1. The employment of increasingly higher effort levels, that's over-capitalization.
2. the increased use of fishing gears with reduced mesh size which are indiscriminate in their catch
3. Uncontrolled cutting of mangroves and destruction of coral reefs.
4. The increased use of dynamite, thus reducing the environmental carrying capacity.

From Figures 4.1, the relationship between the number of vessels (Effort) to yield shows that effort level have surpassed the maximum level. This relationship indicates that the optimal level of production was approximately 52,000 tons, with 4,375 vessels and 15,834 fishermen. Thus there is already overfishing. If we use decline catch per unit effort as an indicator. As the moving average line shows.

Fig. 4.1 **Results: YIELD - EFFORT CURVE**

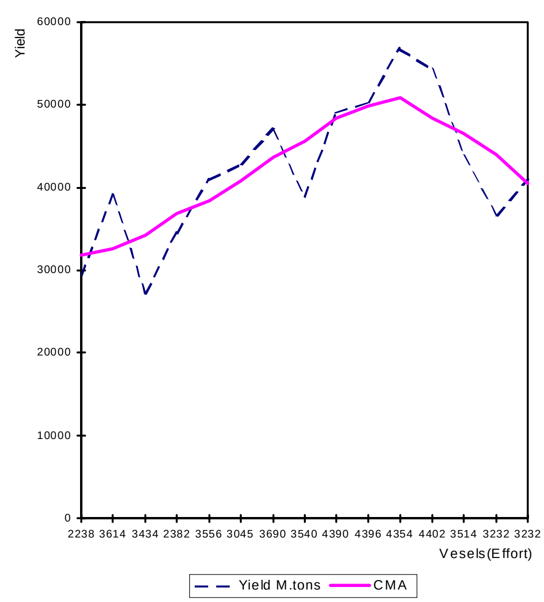

Figure 4.2 shows the trends in the catch and effort levels from 1980-1996. From 1980-83 there is an increase in both catch and efforts (i.e. boats and fishermen). Boats showed a slight increase from 1980-86, but catch and the number of fishermen showed a fluctuating trend with a sharp increase during 1984 - 85. From the ERP period (1986) there is marked a sharp increase in both catch and number of efforts implying that with liberalization modern fishing efforts into deep waters were introduced and hence more catch. This trend continued up to 1991

when the maximum catch was reached as well as maximum number of fishermen.

Table 4.2 The Trend in Catch Rates (Catch per Fisher and Catch per Vessels) of Artisan Fishery 1993-1996

3.1.1 Major Factors Accounting for the Fall in Catch

Generally therefore, major factors that have been cited to contribute to the fall in catch, among others are dynamite fishing, the use of trawlers, and a general increase in the effort levels, (fishermen, fishing gears and vessels). In deed, dynamite fishing has destroyed many coral reefs that are important breeding grounds. Uncontrolled mangrove cutting has also contributed to the fall. It has been observed that coral reefs and mangrove forests increase the carrying capacity of the resources. Hence their destruction reduces the capacity of the environment to accommodate large stocks. This leads to a reduction in the stock levels[4] as shown in Figure 2.1. Less stocks means less catch. *This therefore suggests that the decline in catch should not only be judged on the basis of increasing effort level. Other aspects such as these should also be taken into account for the proper formulation of mitigative policies.*

[4] Point X-Xc is the carrying capacity. With the destruction of coral reefs and mangroves means the stock that can be accommodated will be less than those at Xc. Assuming that Xc depicts maximum stock levels (i.e. when the environmental carrying capacity was intact)

3.2 Quantitative Results

This section presents and discusses the empirical findings of the study. In this section two models have been estimated, that is artisan model and commercial fishing model. The most common problems in econometric studies were tested for. These include multi-collinearity, autocorrelation and heteroscedasticity. Multi-collinearity was tested through examining the correlation coefficient matrix. The problem was detected to exist and was solved by using appropriate technique. The other problem, which was detected, is autocorrelation, using Durbin-Watson test . (Green W.H 2000). The standard measure of outocorrelation, Durbin Watson (DW) statistics suggests that, for the best result, the DW statistics should lie around 2. The appropriate tests were conducted and the entire model was found to have outocorrelation problem.

Bioeconomic Model: Results

Model in (A8) equation was estimated by regressing the catch per effort data for each fishery on the corresponding effort data. The regression analysis was done first for traditional fish catch and for commercial fish catch.

1. **Traditional fishing**

A: Catch/Fisher = 7.3233 - 0.000312*Fisher
(8.919) (-5.202)

Adj. R^2 = 0.64 RSS = 4.82309 F(1,15) = 27.065[0.0001]
Durbin-Watson Test = 1.8

B:Catch/Boats = 23 .531 - 0.003036*Boats
(8.377)** (-3. 947)**

Adj. R^2 = 0.51 F(1,15) = 15.577[0.0013] RSS 230.967356 Durbin Watson Test = 1.5

2. Commercial Fishing.

A: Catch/Effort = 0.4638 - 0.0002512*Effort
(2 .670)** (-2.006)**

Adj. R^2 = .65 Durbin Watson Test = 1.6

Note: * significant at one percent level
** significant at five percent levels
Numbers in the brackets are t-values.

Results above are the bioeconomic model which are assumed to be parabolic. The models were estimated by regressing the catch per effort data on the corresponding effort data (boats/Fishermen) for both traditional and commercial fishing. Also for the case of traditional fishing number of fishermen are considered separately as efforts (model A).

As expected, the coefficient of effort is negative in all regressions. Both regression models the coefficients are significant at the conventional 1 and 5 percent level. For commercial fishing the regression is significant at 5.

Figures 2.1 and 2.2 predict that catch should increase with efforts up to the MSY point, decrease as efforts increase beyond this point. In the commercial fisheries, the MSY point occurs at an effort level of (234.07) units of boats. The corresponding catch is 449.54 tons.

Sustainability and Efficient Issues

To establish the ecological sustainability of current fish harvesting practices, an estimate of the maximum sustainable yield was made and compared with the actual catches. Basing on this the decision criterion was that if level of effort (i.e. boats and fishermen) and the total catch exceeded the MSY level then the fishing activities would be regarded as unsustainable.

Basing on equation (A8), we found that the maximum sustainable level of boats was 3,847 units. This level when compared with the recorded number of boats suggests that the marine fisheries sustained excess capacity of boats from 1988 to 1991 there after declined with a fluctuating trends. Substituting this figure, i.e. 3,847 into model results B we observed that the corresponding maximum sustainable yield was 41,267 tones of fish. When compared with the actual catch there was overfishing for about seven years out of 16 years, almost half the period, the catch trend started to decline from 1991 suggesting the depletion of the species. On the model results A, using the number of fishermen as efforts, the maximum sustainable level of effort was 11,743 units, and the corresponding catch is 42,997 tons. Comparing these figures with the actual number of fishermen and catch recorded we found that marine fishing sustained excess capacity of fishermen for 10 years out of 16 year, that's more than half of the period and there was overfishing for almost seven years. On the basis of the criterion stated earlier the current traditional fishing is not sustainable. Thus there is a need to institute appropriate measures

Since E_{msy} shows the maximum in the yield-effort curve, on the basis of Figures 2.1 and 2.2 and if we can assume the curves to be normally distributed, then for the yield to be zero i.e. resource to be drawn into extinction, effort has to be increased twice of its maximum level

$$
\begin{aligned}
E_{extinction} &= 2 * E_{msy} \\
&= 2 * 3,847 \\
&= 7,694
\end{aligned}
$$

This implies that if the number of effort is left to grow to as high as 7,694 then according to the model the specie would be drawn to extinction[5].

Maximum Economic Yield (MEY)

From an economic perspective, effort relative to the MSY point is not the relevant issue. We are interested in the resource rent. As long as the cost per unit of fishing effort is positive, a fishery harvested at the MSY level is economically overfished. Resources rent is maximized at lower level of effort, the MEY level. The MEY point however, depends on prices and costs and therefore is not constant overtime. It will vary as the price of catch and inputs change: high price of effort will reduce the amount of efforts (i.e. number fishermen and of boats). The MEY level of catch and efforts in 1992 was 42,164 tons and 2817 units respectively. When this is compared with the actual catch and efforts in the same period we find that the fishing sector sustained economic overfishing (as shown in Table 3.1). Table 3.1 shows slight underfishing during 1983 - 1986, and overfishing during 1987 - 1992. During the same period of overfishing the number of large trawlers and purse seiners increased to more than 16. After that, retirement of smaller vessels reduced the overall level of effort and the degree of overfishing.

4.0 CONCLUSION AND POLICY RECOMMENDATIONS.

The objective of this study was to empirically analyze the exploitation of marine fishing in Tanzania. It was deemed important to undertake this study for the purpose of investigating the applicability of fishing model in Tanzania marine resources. Based on the findings some policy implications and recommendations are made.

4.1 Summary and Policy Implications

The study observed some of the environmental problems, these are for example; (a) the use of crude gears such as small mesh size nets which catch mostly juvenile and hence reduce the future stocks of fish, (b) lack of enforcement of existing legislation banning the use of poisons and establishing minimum mesh size, (c) due to lack of alternative sources of subsistence, marginal population particularly among the youths have been pushed into the fisheries sector as last resort resulting into the over-capitalization of the fishing sector and hence over-exploitation of the resources, (d) pollution of fishery resources from land based activities such as sewage and solid waste from urban area along the coast, particularly

5The Fox model does not consider complete extinction of resources. What is believed in the model is that the curve will move asymptotically

Dar Es salaam, Tanga, Lindi and Mtwara due to inadequate collection and treatment, (e) also there is an increasing mangrove cutting for timber, poles, fuelwood, charcoal and local medicine. Uncontrolled cutting of mangroves which serves as feeding and nursery areas for prawns, shells fish and other fish species leads to reduction of the stock. This problem is noted to be severe particularly in Pangani, Rufiji and Bagamoyo.

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There is a serious conflict almost everywhere along the coast particularly where there are trawlers. The problem with this is the fact that these trawling takes place in the same inshore waters that are also used by artisan fishermen and these are the very same ones believed to be over-exploited. Also complains are there that the trawlers fish day and night (24 hours) instead of the 12 hours a day that are recommendable. Thus, close monitoring of this is needed.

The majority of fishermen are poor and use low quality fishing gear and vessels. This can explain why they are concentrating in inshore waters. Also, 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.

Cases that contradict previous findings as the dwindling fish stocks with the increasing effort found: In Bagamoyo, it was found also that there are a lot of fishermen coming from Zanzibar, Tanga and Kunduchi who hoped that there were abundant catches there than where they are from. The majority of the fishermen interviewed in Bagamoyo agreed that the increase in the number of fishermen was a problem as far as fish availability was concerned. This evidence is contrary to other previous studies (Maliyamkono, *et al* 1994; Maghimbi, 1996) which showed that fishermen do not see the increase in fishing efforts as a problem that was to be related to dwindling fish stock

Based on the findings the following policy implications can be drawn. It has been found that exploitation has already reached and surpassed the maximum sustainable level (it is in the declining portion of the Yield-Effort curve (2.2). In view of this, there is need to undertake regulatory measures to preserve the species (implying reallocation of resources from that combination existing under open access to a controlled system designed to maximize the net value of production for the economy as a whole).

Policies that recognize and incorporate indigenous communities will most likely be successful if sufficient authority and power are delegated to the local level. Empowering the communities instills in them the direct responsibility for management and protection of the fishery resources and other marine resources in general. Equally important is the need to educate local communities on the effects of marine resources destruction and the benefit from well managed marine resources. Once aware of such benefits, communities are move opt to adopt conservation methods and to ensure that methods are adopted by other communities and groups as well.

In this regard the idea of community based marine conservation, for example, the Mafia case is a promising approach. A great emphasis is placed on involving local communities in research, education, and training program. Local people are integrated into the management system and their indigenous knowledge of fishes and other marine resources is utilized in designing management.

With this therefore, regulations for conservation measures need to be imposed mainly for two reasons; to preserve the fish stock from destruction and depletion and to protect the economic position of the fishing community. In the implementation of the regulatory measures the following need to be considered; (a) the policy should be flexible enough to allow for proper reaction to changes in economic and biological conditions, (b) to involve the participation and support of the local communities as this will ensure minimum resistance.

Generally therefore, systematic research on the ecological of the commercially important stocks available should be carried out. In addition, better monitoring data on catches and efforts are needed for a proper and viable management.

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Appendix A

A.0 METHODOLOGY

To be able to undertake the economic analysis of marine fisheries, data was gathered on the following variables. (I) the catch (ii) the effort (iii) the average price of the fish (iv) the cost of fish harvesting. The data on the catch and effort were obtained from the department of statistic and the landing sites. The catch was expressed in weight of biomass while the effort which is a composite of input was expressed in terms of the number of boats, boats days, the number of nets and the sizes of the nets. With regard to fish price and the cost of fish harvesting, the market values were used. There was great variability in fish prices both between different markets and between various points in time. This necessitated the use of averages.

A1.1 Choice of the Model and Description of Variables

The model to be used is that of renewable resource, its choice being motivated by its relevance to the topic of the study. The model try to clarifies the roles of commercialisation, population growth, and the breakdown of the traditional management systems in the depletion of resource stocks. The model includes a biological production function (bioeconomic model) and profit function. The variable catch was expressed in weight of biomass while the effort which is a composite input is expressed in terms of the number of boats, boats days, the number of nets and the sizes of the nets.

A1.2 Model Specification

The model will focus on assessing the level of exploitation of fishery in Tanzania marine waters with a view of establishing whether there is overfishing or not. And establishing whether fishing is undertaken in efficiency ways. To be able to assess this the following will be considered; (1)-interviewing fishermen to gather their perception on the level of exploitation of fishery. (2) By looking at the trend of the catch can also indicate whether there is overfishing. In this if total catch is declining as effort increases, then there is a likelihood of biological overfishing which imply that economic overfishing has already occurred.

A1.3 Bioeconomic model

Economic models of fishery are underlined by biological models. It is impossible to formulate any useful economic model of fishery without specifying the underlining biological dynamics of the fishery. The bioeconmic model is based on the classic Gordon-Schaefer model, (Clack, 1976), which assume that growth of the fish is a quadratic function of the stock[6].

A1.3.1 Biological Model

A biological model of multi-species fishery is generally complex but a single species model can capture its essentials. We have therefore built our model assuming a single species fishery. The fishery resource model is the only one example of resource harvesting models that are based on the elementary differential equation. In this model the rate of surplus growth is defined as

$$F(Xt) = \alpha X_t(1 - X/K). \ldots\ldots\ldots\ldots\ldots\ldots(A.1)$$

Where X_t = the stock of fish at time t, K is the environmental carrying capacity, α = the maximum proportional growth rate, t is the index of time. This implies a parabolic growth curve which is depicted in Fig. 2.1 The equilibrium in this model is reached when the stock of fish is equal to the environmental carrying capacity. That's X = K. That is why K is termed as the maximum value that X can reach.

Equation (A.1) yields an inverted U-shape growth curve. To obtain the natural equilibrium level of stock mathematically we take the first derivative of equation (A.1).

$$dF(X)/dX = \alpha(1 - 2X/K) \ldots\ldots\ldots\ldots\ldots\ldots(A.2)$$

From this if we can assume that effort always removes a constant proportional of the stock and the catch is always equal to the surplus growth. This model can be transformed in a very simple way to a catch- effort model. This is possible by assuming that efforts responds to the change in price. Given the assumption, we therefore transform our model into catch-effort model. With the catch per unit effort being proportional to the stock, we can write;

$$Y = EqX\ldots\ldots\ldots\ldots\ldots\ldots(A.3)$$

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[6] More sophisticate models that account for the age structure of the fish population can be estimated if sufficient detailed data are available. This was not the case for Tanzania. For an exposition of such models, see Deriso (1980), and Shnute (1985). For evaluations of their empirical performance see Roff (1983), Deacon (1989)

where Y = catch, q = a factor of proportionality ie. catchbility coefficient, E = effort.

Setting Y = F(X) gives,

$Y = F(X) = \alpha X_t(1 - X_t/K)$

$Y = \alpha X_t(1 - X_t/K)$ ....(A.4)

$Y = \alpha X - \alpha X^2/K$

But we know that Y = qEX from (A.3)
Implying therefore that

$qEX = \alpha X - \alpha X^2 /K$, multiplying by_K/X throughout gives,

$KqE = K\alpha - \alpha X$, solving for X we obtain;

$X = (K(\alpha - qE))/\alpha$ ....(A.5).

Using equation (A.5) in (A.3) yield;

$Y = EqK(1 - qE/\alpha)$ ....(A.6)

Since q, K and α are all constant parameters, we can express the following as:

$Y = \beta_1 E - \beta_2 E^2$..(A.6')

where $\beta_1 = qK$; $\beta_2 = q2K/\alpha$

Dividing through by E we get the catch per unit efforts as a linear function of effort. Since data on effort and catch are readily available in Tanzania, this allow us to estimate the parameters β_1 and β_2 by linear regression of the catch per unit of effort on effort:
That's;

$Y/E = \beta_1 - \beta_2 E$...(A.7).

Economic Model

In this model the relationship between cost and effort is assumed to be linear, then total cost of fishing effort will be defined as;
$TC(E) = \alpha E$

where α denote the unit cost of fishing and E the unit of effort. A positively sloped linear cost curve and constant marginal cost curve would be obtained as depicted in Figure 2.1

Economic Optimum

Given the average price of fish and the long term cost per unit of efforts, the long term economic optimum is where the marginal sustainable yield is equal in value to the cost of an addition unit of effort. The marginal sustainable yield is obtained by calculating the first order condition of equation (6');

That's $dY/dE = \beta_1 - 2\beta_2 E$
At the maximum dY/dE = 0;

Hence $0 = \beta_1 - 2\beta_2 E$

$\beta_1 = 2\beta_2 E$

$E = \beta_1 / 2\beta_2$...(A.8)

The value of which is;

$P(dY/dE) = P(\beta_1 - 2\beta_2 E) = MR$

Hence setting $P(\beta_1 - 2\beta_2 E) = MC(E)$..........................9)

At a point where MR=MC(E) is the MEY which gives the optimum yield and a sustainable profits.

Figures obtained here therefore is compared against the actual catch and the actual number of efforts. To find the equilibrium effort under open access we set the value of catch per unit of effort equal to the cost per unit of effort.