POSSIBLE ECONOMIC IMPACT ON COASTAL FISH STOCK RESOURCES IN BANGLADESH IN THE CASE OF CLIMATE CHANGE

By

Ahasan Habib

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The Norwegian College of Fishery Science

University of Tromso, Norway

&

Nha Trang University, Vietnam

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ABSTRACT

The Bay of Bengal fishery in Bangladesh is the most important and the predominant fishery in the country. Effort data from 1985-1986 to 2007-2008 is standardised to a standard year 2007-2008 (fish trawler) vessel and standardised effort has together with catch data been used to calculate the parameter values for the Gordon-Schafer surplus production model. The parameterised models are used to estimate the biological parameters, maximum sustainable yield, maximum economic yield and open access equilibrium. The analysis indicates that present level of effort in the fishery is very close to the level of maximum sustainable yield (of about four thousand tonnes), but increase in cost and population related to recent changes in fishing pattern may show this situation is unsustainable. The model results are not pointing at any severe biological overfishing. But, on the other hand, economic overfishing started several years before. The model has also been studied under nine climate scenarios where assuming each represents possible climate change consequences. Similarly the output of three reference equilibriums have been studied for each climate scenarios.The paper analyses the potential of climate effects for changing the intrinsic growth rate, carrying capacity, profitability by the Bay of Bengal fisheries.

Keywords: Bangladesh fishery, bioeconomics of fishery, economic impact, climate change.

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1. INTRODUCTION

1.1 History of fishery

The history of fishery sector development and policy in Bangladesh according to (Hossain et al., 2006) can be divided into three main periods. The first period is the pre-colonial up to 1757. The second period is the colonial period from 1757 to 1971, before independence. And the last period runs from 1971 to now and is called the post-colonial period after independence. Before the independence period the fisheries sector was not well developed. Fishery policy and management were also poorly developed due to several reasons. One reason was that the country was considered being a potential market for Britain and Pakistan. This implies that the country was importing fish products while the fishery industry in Bangladesh was basically artisanal and undeveloped. Local fish products were only used for subsistence level and domestic markets. However, spread along the main port city of Chittagong were semi-industrial and industrial fisheries limited in terms of number of vessels that was commercially oriented.

After independence the semi-industrial and industrial fleet were increased in terms of numbers and capacity. Bangladesh marine fishery sector is divided into two sub sectors one is artisanal fishery and another is industrial (trawl) fishery. Trawl fishing is one of the most important sectors in marine fishing in Bangladesh with respect to export, domestic consumption and other aspects of the economy. Commercial fishing started since in the early 1972, after liberation. Furthermore, Bangladesh started with a fleet of 10 trawlers after liberation i.e. 1972-1973. The numbers of trawler fleets more than doubled to 21 in a year and then jumped to 26 two years later (Khan, 2007). The current (in 2007-2008) number of trawlers is 133 of which 38 are shrimp trawlers and the remaining are fish trawlers (Statistics of Marine Fisheries Department). But after independence they left the country for several reasons and the Government at that time took over management of all such investment. This meant that the fishing industry of the country was totally centralised. Furthermore, Hossain et al., (2006) described about management policy, major objectives and major achievement. From 1971 to till date (post-colonial time) many management initiatives has been taken by government but most of them has not been specific conservation arrangements and poorly implemented due to lack of inter-sectoral coordination (Hossain et al., 2006). Until now, government has been privatising the fishery industry which is called the “leasing system” and by this increased the catch from the public fishing grounds and thus provided immediate returns to the national exchequer in Bangladesh. From the early 1990s several projects introduced aspects of community-based management to fisheries (Sultana and Thompson, 2007).

A free market economic regime has been ushered in and which is meant that more investors coming into the fishery. Eventually, the capacity and dynamic of the fishery industry was greatly improved in respond to the new market demand created.

1.2 Scope of study

This study has been concentrated on: Possible economic impacts on coastal fish stock resources due to climate change and it has been compare to impact from changes in management as well. Specifically, this paper has made assumptions on climate effects on r (intrinsic growth rate) and K (carrying capacity) in a surplus production model of the ecosystem by estimating the value of them (r and K). In addition, three different reference equilibriums have been tested out in response to the assumed effects of climate change.

1.3 Climate change and regional effects

Climate change is now a scientifically established fact. It is a change in the statistical properties of the climate system when considered over periods of decades. Climate change maybe limited to a specific region or may occur across the whole earth. Eide (2007) described that global warming is overwhelmingly documented by a vast number of scientific studies over the last ten years. This issue is a matter of concern all over the world. Fisheries production is related to climatic conditions and fisheries have always been affected by variable climate (Daw et al., 2009). Nevertheless, Bangladesh is already affected and will be hit hardest by climate change (CCC, 2007) and according to MOFE (2008) climate change will severely challenge the country’s ability to achieve the high rates of economic growth. Therefore, this is a very crucial issue as a developing country. Bangladesh is globally considered as one of the most climate vulnerable countries (CCC, 2007; Ali, 1999; MOFE, 2008). According to Ali (2007) coastline of Bangladesh seems to be particularly vulnerable and quite sensitive to coastal erosion due to climate change as well.

The biological and ecological values of Bay of Bengal are very important. Large number of commercially important fishes occupied in this Bay and it has been contributing the economy of country. This Bay is the main source for fisheries in this country as well. However, fisheries sector of this country may also be adversely affected by climate change (Ayers and Huq, 2008). As a result natural fry production may be reduced. Anon (2001) also mention that sea temperature affects the biological production rate and, hence, food availability in the ocean, which impact on fish abundance and distribution. In the case of Bangladesh there are 475 species of fish have so far been identified from the coastal and marine waters of the Bay of Bengal (Islam, 2003). Among them, there are 260 species of fish in Bangladesh, all of which are sensitive to particular salt and freshwater condition; the change in tidal patterns, increasing saline intrusion into the freshwater rivers due to climate change and it will impact on fish populations (Ayers and Huq, 2008). In addition, climatic factors affect the biotic and abiotic elements that might influence the numbers and distribution of fish species. The abiotic elements include water temperature, salinity, nutrients, sea level and current conditions while biotic factors include food availability and presence and species composition of predators and competitors and finally affect the food web and whole ecosystem. In contrast, Allison et al., (2007) refer that, it is a research challenge to predict impacts of climatic change at present and find out biophysical variables; moreover it is not clear what the relative importance of each individual impact pathway would be and how indirect effects would affect fisheries. Besides, climate also affects on primary production but primary producers have been play very important role for fish production or recruitment and abundance. The primary production of Bay of Bengal is higher especially during the fall intermonsoon followed by summer monsoon and spring intermonsoon (Kumar et al., 2006). Therefore, climate change will affect primary production of the Bay and thus fishery sectors would be affected.

Nevertheless, a wide range of potential indirect ecological, direct and indirect socioeconomic impacts on fisheries have been identified (Allison et al. 2005). Socioeconomic condition of fishermen is closely related to fishery resources or abundance. Daw, et al., (2008) also identified that there is an impact on aquatic ecosystems in terms of biophysical effects. These have been the focus of most studies of climate change and fisheries and interaction with each other. Many research and researchers have been mentioned about interaction or impacts of climate on fisheries.

2. THEORY AND DATA ESTIMATION PROCEDURES

2.1 Reference equilibriums and management regimes

The overall goal of fisheries management is to produce sustainable biological, social, and economic benefits from renewable aquatic resources. The three reference, equilibriums open access (OA), maximum economic yield (MEY) and maximum sustainable yield (MSY), represent different fisheries objectives which is the basis of identifying suitable management measures. MEY may for example be obtained in different ways, i.e. limited entry, quota regulation and other means.

Reference equilibriums could be represents two different ways of managing the resources, keeping the catch constant even when the stock biomass changes, or keeping the fishing pressure constant, even when this will reduce or increase the catch and also could keep the stock sustainable or constant even when catch will reduce or increase.

2.2 Environmental scenarios

Nine environmental scenarios have been considered, including the present situation (Scenario 0). The scenarios are based on from the model where each scenario represents possible climate change consequences. The following nine scenarios are included:

0. Current climatic situation (i.e. r and K as now)
1. Growth rate change by 10% (i.e. r-10% and K as now)
2. Growth rate and carrying capacity both change by 10% (i.e. r-10% and K-10%)
3. Carrying capacity change by 10% (i.e. r as now and K-10%)
4. Growth rate change by 25% (i.e. r-25% and K as now)
5. Carrying capacity by 10% and growth rate by 25% (i.e. K-10% and r-25%)
6. Carrying capacity change by 25% (i.e. r as now and K-25%)
7. Growth rate change by 10% and carrying capacity by 25% (i.e. r-10% and K-25%)
8. Growth rate and carrying capacity both change by 25% (i.e. r-25% and K-25%)

Among these scenarios 1, 2 and 3 are most likely to happen for the Bay and other scenarios assume a significant reduction in the present flow of the Bay. Scenario 0 maybe acts as reference scenario.

2.3 Models

2.3.1 Model's choice and description

The surplus production model has been selected for this study because, it is simple and easy to incorporate environmental impacts and its parameters can be estimated using catch and effort data, furthermore this model is especially well fitted and easy to identify the potentially serious impacts (Jensen and Marshall, 1982). One of the main aims of this study is to investigate the potential impacts of climate change on fish stock resources of the Bay of Bengal. Therefore Gordon-Schafer surplus production model (GS) has been selected for this thesis. The GS model originated from Gordon (1954) and Schaefer (1957, described in Flaaten, 2009). Biological reasoning (included biological models) has been used as tools for better inform fisheries management, both for the planning and implementation stages as well as to evaluate management strategies. This model has big advantage of requiring limited data and given stated political objectives this model would produce rough guidance on fleet size in the case of single-species and multi-species fishery as well.

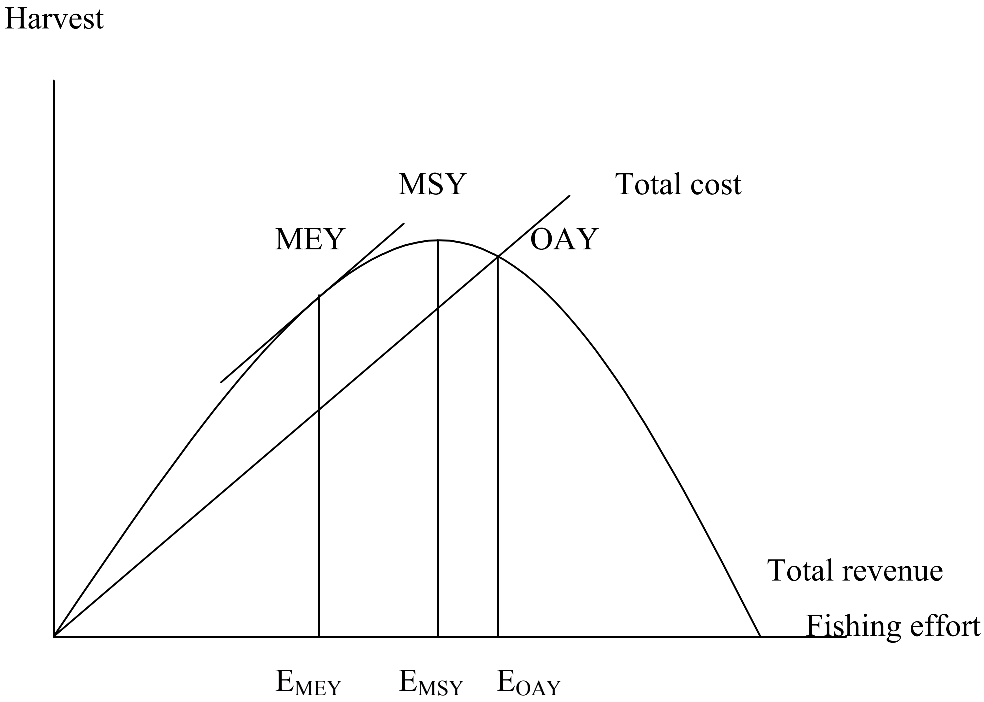

Fig 2.1: A catch-effort curve.

2.3.2 Bio-economic model

According to Flaaten (2009) fisheries based on biological highly productive resources with large *r* (intrinsic growth rate) and *K* (carrying capacity) may sustain a large fishing effort under open access. In all populations natural surplus growth is small for both high and low stock level and largest for some intermediate level. The Gordon-Schaefer (GS) model is based on the logistic growth equation:

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

Where *F(X)* is surplus biomass growth per unit of time; *X* is stock biomass. The equation describes a parabolic curve as a function of X.

Schaefer catch equation is a bilinear short-term harvest function and it assumes that effort always removes a constant proportion of the stock.

$$H(E,X) = qEX \tag{2}$$

Where *H* is catch per unit of time measured in terms of biomass; *E* is fishing effort and *q* is a constant catchability coefficient. Sustainable yield occurs when harvest equals the surplus growth, i.e. when *rate of change of biomass*, $\frac{dx}{dt} = F(X) - H(E,X) = 0$. This implies $qEX = rX\left(1 - \frac{x}{K}\right)$ based on equation (1) and equation (2). Biomass at equilibrium, *X,* is solved to be

$$X = K\left(1 - \frac{qE}{r}\right) \tag{3}$$

Inserting equation (3) into equation (2) gives the long term catch equation

$$H(E) = qKE\left(1 - \frac{qE}{r}\right) = qKE - \frac{q^2 K\, \mathrm{E}^2}{r} \tag{4}$$

Dividing both sides of equation (4) by effort (*E*) gives the linear relationship between catch per unit of effort (CPUE) and fishing effort:

$$CPUE = \frac{H}{E} = qK - \frac{q^2 KE}{r} \tag{5}$$

Assuming constant price equations (4) can be used to define total revenue (TR) in equilibrium as a function of standardized effort:

$$TR(E) = p.H(E) \tag{6}$$

Where p denotes a constant price per unit of harvest. Total cost of fishing effort (TC) is given by:

$$TC(E) = c.E \tag{7}$$

Where c denotes unit cost of effort including opportunity cost of labor and capital.
Equation (6) less equation (7), gives the equilibrium resource rent (∏) as a function of fishing effort (E)

$$\prod(E) = TR(E) - TC(E) \tag{8}$$

3 DATA AND PARAMETER ESTIMAES

3.1 Fish catch and fishing effort data

In order to carry out the study, time-series of data (1985-1986 to 2007-2008) have been gathered on catch and effort (Table 3.1 & 3.2) of Bay of Bengal fishery, Bangladesh. Data have been obtained from the statistics of Marine Fisheries Department, Chittagong, Bangladesh. Catch has been expressed in weight of biomass in tonnes and effort has been expressed in terms of fishing days. Data has been collected every economic (i.e. 1985-1986) year by Marine Fisheries Department. In this study data presented (in table) by economic year and in text the economic year has been written as single year i.e 1985 (which is 1985-1986), 2007 (2007-2008) and so on for all the year.

Table 3.1: Total catch and effort data of the Bay of Bengal, Bangladesh from Shrimp trawlers. (Source, Statistics of Marine Fisheries Department, Chittagong, Bangladesh)

Shrimp trawlers						
Year	Number of trawlers	Shrimp (tonnes)	Fish (tonnes)	Fishing days	CPUE Fish	CPUE Shrimp
1985-1986	31	3716	2317	5794	0.400	0.641
1986-1987	31	4178	3099	6429	0.482	0.650
1987-1988	33	3361	2457	6642	0.370	0.506
1988-1989	42	4830	4487	7806	0.575	0.619
1989-1990	44	3134	6157	7394	0.833	0.424
1990-1991	42	3652	3526	5658	0.623	0.645
1991-1992	46	2621	4747	5529	0.859	0.474
1992-1993	37	3903	5494	6588	0.834	0.592
1993-1994	40	3453	5670	7113	0.797	0.485
1994-1995	43	2391	4894	6691	0.731	0.357
1995-1996	41	3554	3803	6502	0.585	0.547
1996-1997	41	3508	4233	6914	0.612	0.507
1997-1998	48	2419	5714	7044	0.811	0.343
1998-1999	41	3709	5373	7645	0.703	0.485
1999-2000	44	2908	5372	7152	0.751	0.407
2000-2001	44	3155	4701	7289	0.645	0.433
2001-2002	44	3142	4459	6935	0.643	0.453
2002-2003	45	2455	5447	7069	0.771	0.347
2003-2004	45	3059	6034	7442	0.811	0.411
2004-2005	45	3272	5038	7866	0.640	0.416
2005-2006	41	3377	3544	7466	0.475	0.452
2006-2007	39	2138	3769	5919	0.637	0.361
2007-2008	38	2579	2362	5969	0.396	0.432

Table 3.2: Total catch and effort data of the Bay of Bengal, Bangladesh from Fish trawlers. (Source, Statistics of Marine Fisheries Department, Chittagong, Bangladesh)

Fish trawlers						
Year	Number of trawlers	Shrimp (tonnes)	Fish (tonnes)	Fishing days	CPUE Shrimp	CPUE Fish
1985-1986	14	315	5500	1783	0.177	3.085
1986-1987	18	311	4769	2351	0.132	2.028
1987-1988	19	184	4393	2331	0.079	1.885
1988-1989	8	32	931	617	0.052	1.509
1989-1990	8	1	2105	990	0.001	2.126
1990-1991	12	44	1532	721	0.061	2.125
1991-1992	14	281	1974	1421	0.198	1.389
1992-1993	12	285	2545	1545	0.184	1.647
1993-1994	11	27	3305	1228	0.022	2.691
1994-1995	14	25	4404	1354	0.018	3.253
1995-1996	12	33	4568	1432	0.023	3.190
1996-1997	14	28	5793	1656	0.017	3.498
1997-1998	13	25	7515	1856	0.013	4.049
1998-1999	18	55	6680	2136	0.026	3.127
1999-2000	21	6	8017	2517	0.002	3.185
2000-2001	31	17	16027	3871	0.004	4.140
2001-2002	36	26	16586	4841	0.005	3.426
2002-2003	42	22	19428	5414	0.004	3.588
2003-2004	49	17	23207	6284	0.003	3.693
2004-2005	68	38	25895	8535	0.004	3.034
2005-2006	78	67	27096	11469	0.006	2.363
2006-2007	88	36	29446	11462	0.003	2.569
2007-2008	95	41	29176	13368	0.003	2.183

3.1.1 Fish catch (fish trawlers)

From 1985 to up to now, over all catch and effort have not changed very much in the shrimp fleets, while the fish trawlers have had a significant increase in catch and effort. Industrial (trawl) fishing is the main harvesters of fish in the Bangladesh Marine waters since commercial fishing started in the early 1972, after liberation. Between 1985and 1988 total annual catch levels were between the range of 5,000 tonnes and roughly 6,000 tonnes. From 1988 to 1999 fish catches have been rising slowly (Fig 3.1) and from the end of 1990s the number of trawlers has been increased steadily up to now.

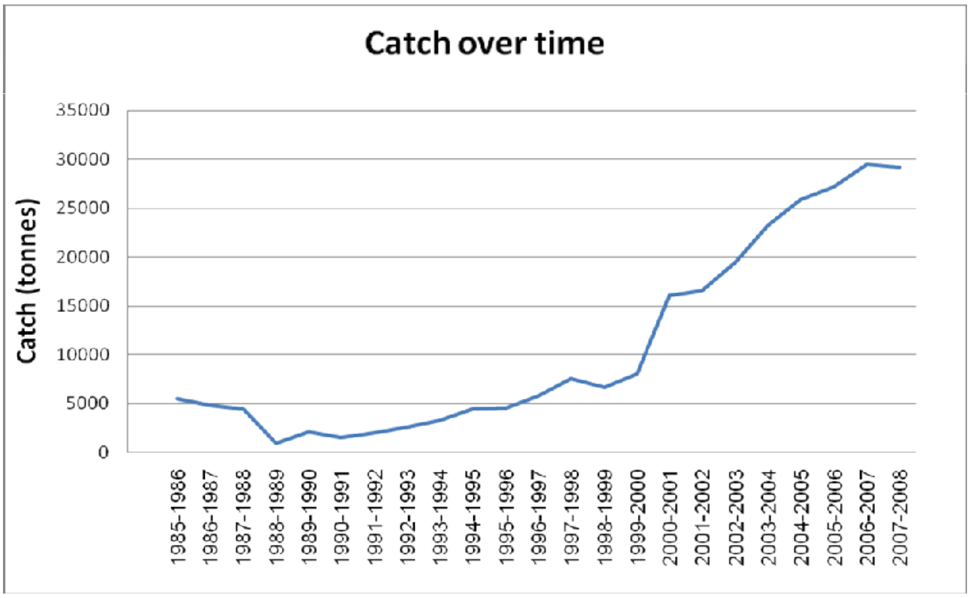

Fig 3.1: Fish catches by fish trawlers (Table 3.2).

3.1.2 CPUEs (fish) by fish trawlers

Except for the first year, the CPUEs were around 1.5-2.5 until 1994 where after it has been 3-4 up to 2005 when it started declining down to the previous level of about 1987. The decline the recent decade signals a decline in the stock. This CPUEs pattern could be explained by the increasingly more efficient and higher effort. Moreover, this declining of stocks may be the result of increased use of reduced mesh size in trawl codends causing more juvenile catches and negative stock effects .

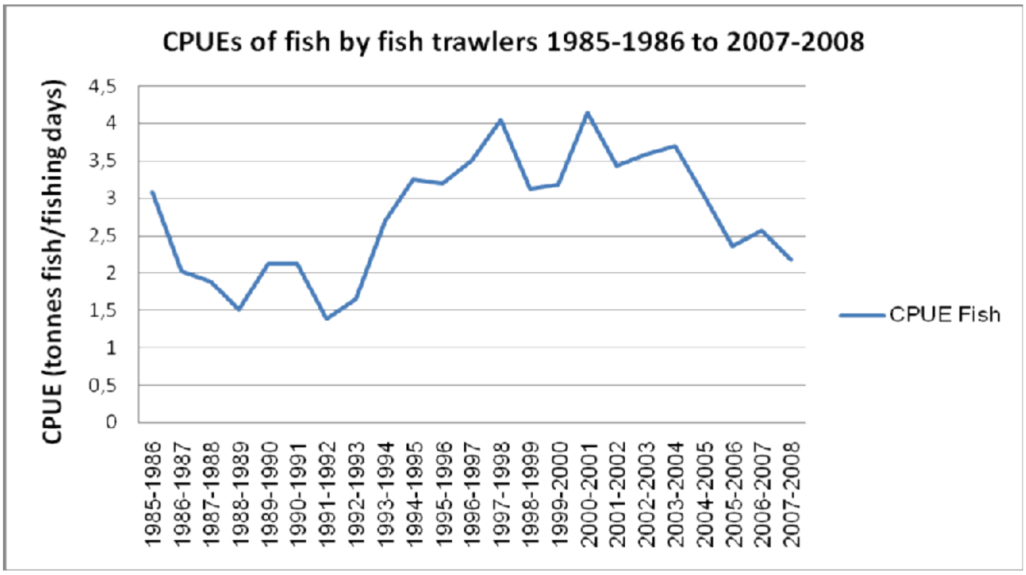

Fig 3.2: CPUEs (fish) of fish trawlers.

3.1.3 Number of trawlers

Bangladesh started with a fleet of 10 trawlers (shrimp) after liberation i.e. 1972-1973 (Khan, 2007). The numbers of trawlers increased sharply after liberation and the last decade there has been a new significant increase in number of fish trawlers. The current total number of trawlers (table 3.1 and 3.2 in 2007) is 133 of which 95 are fish trawlers and the remaining are shrimp trawlers. In the case of the shrimp trawler fleet, number of trawlers has been stable for more than twenty years and then has been decreasing up to now. Fig 3.3 depicts that from 1985 to 2000 the number of trawlers has been fairly stable before and a steadily increase up to now. This may have been the result of fishing is more profitable business because of higher demand and increase of population as well.

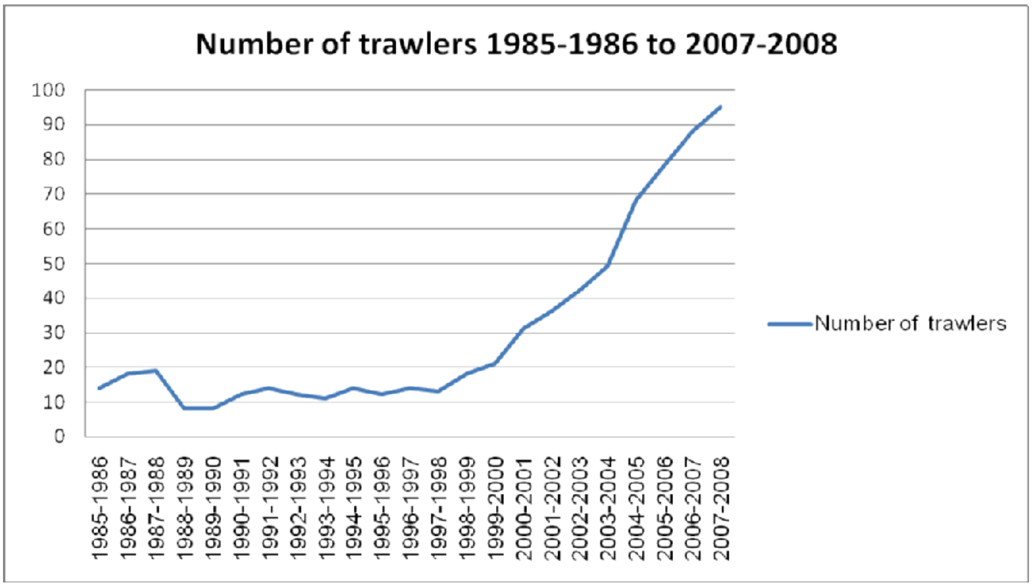

Fig 3.3: Development of fish trawler fleets of Bay of Bengal fishery 1985 - 2008.

3.2 Prices and costs

The average prices of different types of fishes fluctuate in different seasons of the year and size of fish, however group wise price has been shown in table 3.3

Table 3.3: Average price of fishes. (Source, Statistics of Marine Fisheries Department, Chittagong, Bangladesh)

Name of fish	**Price of fish (TK[1]/kg)**
Indian carp *(Amblypharyngodon microlepis)*	100-300
Pangas (*Pangasius pangasius)*	70-100
Tilapia *(Oreochromis niloticus)*	90-130
Rup chanda *(Pumpus chinensis)*	250-400
Prawn *(Macrobrachium rosenbergii)*	200-500
Shrimp *(Penaeus monodon)*	200-450
Bombay duck *(Harpondon nehereus)*	50-100
Jew fish *(Johnius argentatus, Lambu, Kaladatina* etc.)	70-140
Exotic carp *(Hypophthalmichthys molitrix, Ctenopharyngodon idellus)*	60-150
Snake head *(Channa striatus, Channa marulius, Channa punctatus)*	80-200
Singi *(Heteropneustes fossilis)*	500-600
Magur *(Clarias batrachus)*	300-500
Chital (*Chitala chitala)*	400-500
Punti *(Puntius spp.)*	100-150
Tengra *(Mystus tengra)*	180-250
Chapila *(Gudusia chapra)*	150-200
Snapper *(Lutjanus spp)*	100-300
Mola *(Amblypharyngodon mola)*	160-200
Baila *(Glossogobius giuris)*	200-300

[1]TK- is the Bangladeshi currency. The money value is 1USD = 68.50 BDTK

Table 3.3 has been showing the diversity of various species with price. The unit price of harvest and unit cost of fishing effort of the Bay are 50000 TK and 75000TK in 2007 respectively which has been collected from the source of Statistics of Marine Fisheries Department, Chittagong, Bangladesh. This fish price is the price paid in wholesale market.

3.3 Economic parameters

Parameters estimated by regression the catch per unit effort data on the corresponding effort data (table 3.2) for the Bay of Bengal Fishery. In open access equilibrium, average revenue $AR = TR / E$ is equal to marginal cost $\left(MC = TC'(E)\right)$

And for the yield level at open access situation can be found by substituting the effort of Open Access Yield in the equation (4)

$$\frac{pH}{E} = c$$

$$\frac{H}{E} = \frac{c}{p} \tag{9}$$

From equation (5) and (9) give the following equation and it is equilibrium catch per unit effort (CPUE)

Open access stock biomass, $X\infty = \frac{c}{qp}$ (10)

The long term harvest function (4) can be expressed by

$$H(E) = aE + bE^2 \tag{11}$$

Which could be expressed by

$$CPUE = a + bE \tag{12}$$

Where $CPUE = \frac{H}{E}$, $a = qK$ and $b = \left(\frac{-aq}{r}\right)$

Since data on catch and effort are available for the Bay of Bengal 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 (11) by taking partial derivative of H with respect to E and setting it equal to zero as:

$$E_{MSY} = \left(\frac{-a}{2b} \right) \tag{13}$$

And the output at MSY is:

$$MSY = \left(\frac{-a^2}{4b} \right) \tag{14}$$

Further at the open access point, total fishing costs equal to the total revenue from the fishery $(TR(E) = TC(E))$, therefore using the Gordon-Schaefer model the effort at open access yield can be obtained by equating:

$$AR = MC \text{ or } a = \frac{pH(E)}{E} \text{ and } \quad aE = pH(E) \equiv E_{OAY} = \left(\frac{\frac{c}{p} - a}{b} \right) \tag{15}$$

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 (8) $\prod'(E) = 0$ or $\frac{dTR(E)}{dE} = \frac{dTC(E)}{dE}$. Therefore, the effort at maximum economic yield is:

$$E_{MEY} = \left(\frac{a - \frac{c}{p}}{b} \right) \tag{16}$$

Table 3.4 shows parameter values and statistical tests of a linear regression on the basis catch and effort data (table 3.2), assuming equation (12).

Table 3.4 Regression analysis of CPUE on the corresponding effort data from 1985-2007.

Parameters	**Coefficients**	**Standard Error**	**t Stat**	**P-value**
a	3.974	0.208	19.107	3.352E-09
b	-0.0001203	2.85E-05	-4.22	0.0018
Adjusted R square	0.604			

In the regression analysis indicates that about 60% of the CPUE variation is explained by the linear model.

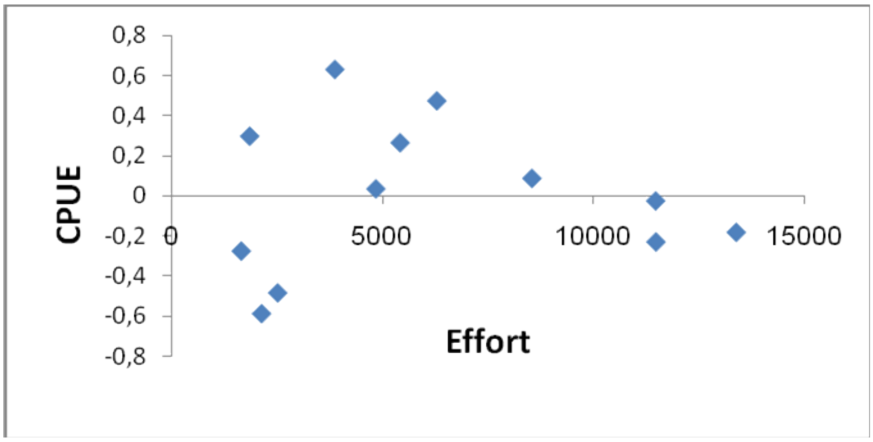

Fig 3.4: Regression analysis of CPUE on corresponding effort.

The regression analysis results shown in table 3.4 above were obtained from time series catch and effort data of the Bay of Bengal fishery obtained from table 3.2. It has been done for the years 1996 to 2007. The period starting 1996 is considered being more reliable data compared with earlier years, also including a more homogenous fleet as well as a more homogenous catch composition. Four major concerns have motivated the use of the shorter time series; Change in accuracy of statistics; catch composition has been changed (i.e more predators early years), corresponding increase in catch while including more prey species; changes in size composition (i.e decreasing mesh size or similar) and change in operational pattern (i.e approaching other areas, longer days). All this factors are regarded to have a significant shift around the year 1996, though all representing smooth changes over longer periods of time.

When $a = qK$ or $K = \dfrac{a}{q}$ (17)

and $b = \dfrac{-aq}{r}$ or $r = \dfrac{-aq}{b}$ (18)

Where q is the catchability coefficient.

4 RESULTS

Intrinsic growth rate and the carrying capacity were calculated based on estimated coefficients, which were derived from (table 3.4) the model. The Gordon-Schaefer model has been predicted the value of K and r is 40660 tonnes and 3.228 by equation (17) and (18) respectively and catchability coefficient (q = 9.77332*10^{-5} in 2003) has been taken from paper of Khan, (2007) from the model for the fishery.

4.1 Yield-Effort curve

The harvest function for the Bay of Bengal fishery based on equation (11), and by injecting parameter estimates from Table 3.4 was found to be:

$H(E) = 3.974E + (-0.0001203E^2)$, where E = fishing effort units from table 3.2

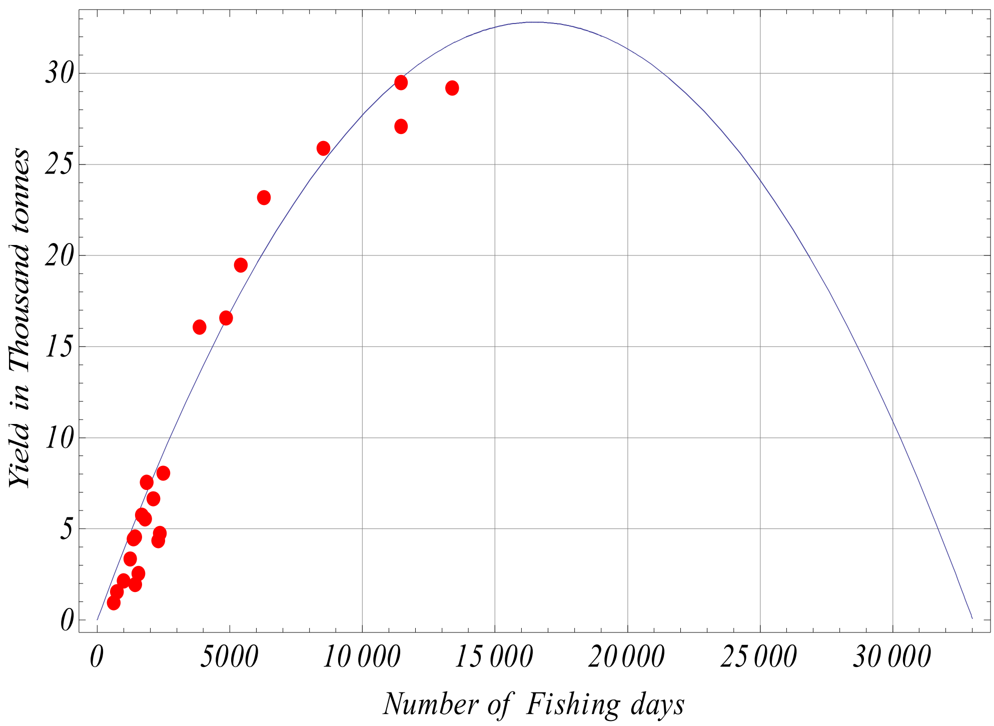

Fig 4.1. Gordon-Schaefer Harvest Curve for the fishery 1985 to 2007 based on equation (11) and catch data from Table 3.2.

4.2 Calculated MSY, MEY, and OA and Corresponding Effort Levels, Economic Rent and in response to changes in the biological parameters.

Calculated reference points of the Gordon-Schafer model for the Bay of Bengal fishery. The values for effort at MSY and MEY have been calculated using equations (13) and (16) in chapter three. Harvest at MSY, MEY and OAY were all calculated using this fishery's harvest equation above.

Economic rent is the difference between total revenue and total cost and these two, that is, total cost and total revenue were calculated using equations (6) and (7) from chapter two as well, respectively.

In order to come up or observe with estimates of change in various level of r and K ; variation was assumed to range between 10% and 25% where a change in K and r also implies changes in harvest, corresponding effort and economic levels as indicated in Table 4.1 below.

Table 4.1 Harvest, corresponding effort and profit at OA, MEY and MSY level in response to changes in the biological parameters K and r with climate scenarios.

	r =3.228- 25%	r =3.228 - 10%	r =3.228
K=40660 - 25%	Scenario 8	Scenario 7	Scenario 6
	E_{OA}= 12304 E_{MEY}= 6152 E_{MSY}= 12385 $\prod_{MEY}$= 227.6*10^6 $\prod_{MSY}$= -6*10^6 H_{OA}= 18454 H_{MEY}= 13781 H_{MSY}= 18455	E_{OA}= 14765 E_{MEY}= 7382 E_{MSY}= 14862 $\prod_{MEY}$= 273*10^6 $\prod_{MSY}$= -7*10^6 H_{OA}= 22145 H_{MEY}= 16537 H_{MSY}= 22150	E_{OA}= 16404 E_{MEY}= 8202 E_{MSY}= 16511 $\prod_{MEY}$= 304*10^6 $\prod_{MSY}$= -8*10^6 H_{OA}= 24606 H_{MEY}= 18375 H_{MSY}= 24607
K=40660 - 10%	Scenario 5	Scenario 2	Scenario 3
	E_{OA}= 14382 E_{MEY}= 7191 E_{MSY}= 12385 $\prod_{MEY}$= 373.3*10^6 $\prod_{MSY}$= 178.6*10^6 H_{OA}= 21570 H_{MEY}= 18251 H_{MSY}= 22146	E_{OA}= 17258 E_{MEY}= 8629 E_{MSY}= 14863 $\prod_{MEY}$= 448*10^6 $\prod_{MSY}$= 214.2*10^6 H_{OA}= 25884 H_{MEY}= 21901 H_{MSY}= 26575	E_{OA}= 19173 E_{MEY}= 9587 E_{MSY}= 16511 $\prod_{MEY}$= 498*10^6 $\prod_{MSY}$= 238*10^6 H_{OA}= 28760 H_{MEY}= 24335 H_{MSY}= 29528
K=40660	Scenario 4	Scenario 1	Scenario 0
	E_{OA}= 15421 E_{MEY}= 7710 E_{MSY}= 12385 $\prod_{MEY}$= 476.9*10^6 $\prod_{MSY}$= 301.6*10^6 H_{OA}= 23128 H_{MEY}= 21101 H_{MSY}= 24607	E_{OA}= 18505 E_{MEY}= 9252 E_{MSY}= 14862 $\prod_{MEY}$= 572.2*10^6 $\prod_{MSY}$= 361.9*10^6 H_{OA}= 27754 H_{MEY}= 25321 H_{MSY}= 29528	E_{OA}= 20558 E_{MEY}= 10282 E_{MSY}= 16517 $\prod_{MEY}$= 636*10^6 $\prod_{MSY}$= 406*10^6 H_{OA}= 30854 H_{MEY}= 28143 H_{MSY}= 32895

Mentioned percentage or amount of changes (growth rate, stocking capacity) due to climate changes is related with decreasing of fish stock and growth developments in the Bay. Percent wise changes have already been applied in the paper of Eide and Heen (2002) as well.

As it can be seen from the above table K and r are very sensitive and had slightly bigger difference between the same percentage change in response to a change in harvest levels. Where as effort levels were smaller difference compare to changes in harvest values. Possible change on effort levels and profit were found to be in the vicinity of about 20000 standard units and nearly TK500million respectively.

5 DISCUSSIONS AND CONCLUSION

5.1 Is There Overfishing in Bay of Bengal's Waters

To examine biological and economic over fishing of fish stocks it is required to know about detailed scientific data on stock levels, regeneration and catch. Pauly (1987) noted that less costly methods such as observing certain indicators like catch per unit of effort, changes of price, changes in market supplies and percentage composition change of species or size over time can be good references to address overfishing. Moreover, declining stock size, a tendency to catch more small-sized individuals, a fall in fish catches, a massive change in catch composition and price rise or drop are indicators of overfishing or fish stocks going to be danger of depletion. 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.

In the case of Bangladesh Marine waters, fishing fleets have increaseed steadily since late 1990's, and CPUE drastically reduced from the late 2000 to now. 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. To get information from fishery Director, it was learned that the fish caught now are smaller in size (9 cm average standard length) compared to what the fishermen used to get in the past two decades ago (Marine Fishery Department). Present condition of high effort, less harvest and less biomass stock indicates that the danger of depletion of the resource cannot be ruled out (Khan, 2007). Fish prices have been 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 biological overfishing but not severe for the fishery resources. Economic overfishing, however, started several years before.

5.2 Major Factors Accounting for the Overfishing

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

The employment of increasingly higher effort levels: Due to 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. Due to absence of alternative employment marginal population particularly among the youths has been pushed into the fisheries sector. Moreover, the trawler fleet, although not permitted by rules and ordinance to fish at depths shallower than 40 m, normally fish upto 30m and even upto 20m depth and as their gear is non-selective, they too harvest sizes of fish and shrimp, which fall under the post-juvenile and pre-adult categories, thereby restricting adult recruitment of a part of the population (Islam, 2003). The everincreasing domestic and international market demand for fishes resulted in the expansion of industrial fishing after liberation. Islam (2003) also mentioned about he estuarine set bag net (ESBN), pushnets and beach seine harvest the members of the same population at sizes much lower than the size at first maturity and, as a result, about 99% of the population do not get a chance to participate in the spawning process. 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 increased use of fishing gears with reduced mesh size: The use of small-mesh nets mainly beach seine nets and gillnets (smaller than the recommended minimum mesh size of 5 cm) in shallow water areas by large number of fishermen or fry collectors has caused considerable damage by the indiscriminate catching of all fishes, large and small, juveniles in the area irrespective of their value. This might have led to local overfishing of specific stocks.

MSY for the Gordon-Schafer model of the fishery of Bay of Bengal has been calculated using equation (14). It occurs when the days of fishing on the Bay is about 16517 as shown in table 4.1. This is about 80% of the number of fishing days on the Bay in 2007. Effort almost doubled in the 5 years starting from 2003 to 2007. It has been assume that there is little difference between the situation in 2007 and that at OAE. Effort at MEY is nearly 76% of that in 2007. This speaks volumes about the economic efficiency of this fishery. The model developed in this study is a mixed species equilibrium model that assumes a open access is common pool. However, the fishery stock depends on several ecological conditions like food supply, water temperature, disease, pollution, currents and so on.

GS harvest curve and yield-effort level are depicted in Figures 4.1 and table 4.1 respectively. Harvests are initially very close to the MSY level, but gradually decline catch per unit effort. The MSY and its corresponding effort level were calculated as 32895 tonnes and 16517 standard units respectively. On the other hand, in case of effort, it has been rising steadily particularly from end of 90' to now. It clearly implies that the higher level of effort causes overfishing which, in turn, causes lower stock. The MEY and its corresponding effort level were calculated as 28143 tonnes and 10282 standard units respectively. Comparing these values with the actual catch and effort figures, the fishery sustained economic overfishing from 2005 up to now. As a result, even higher level of effort in later years does not get adequate quantity of catch. This is obviously alarming and demands immediate attention of policy makers and administrations. In order to protect the resource from depletion or any catastrophic collapse, immediate measures must be taken. Scientific approach also must be adopted for managing this resource.

5.3 Sensitivity analysis

Sensitivity of possible climate change measurement has been considered in respect to carrying capacity, growth rate and economic performance in the case of parameter value has been changed under each regime with individual climate consequences. All scenarios have been described to compare with changing by decreasing conditions and considered under three reference equilibriums.

Scenario 0 (present situation)

This scenario represents the present situation, based on from the estimated K and r value from available data. The harvests are 30854, 28143 and 32895 tonnes at OA, MEY and MSY level respectively and effort level was 20558 at OA level (see table 4.1). The profit level was TK636million at MEY level and TK406million at MSY level. This shows the great importance of the By of Bengal's fishery for the Bangladesh's economy.

Scenario 1

In the case of this scenario the average change or difference was about 10% of harvest levels and change in profit was nearly 11% compare from the current situation (Scenario 0). As a result the possible economic impact is TK63 and TK44million at MEY and MSY level respectively compare to the present scenario.

Scenario 2

The difference of harvest level were 4970, 6242 and 6320 tonnes at OA, MEY and MSY level respectively compare to the current situation. The changes of harvest level were average 20% compare to the current situation. This situation might be happen under any management system which has been discussed. On the other hand, profit impact is about 30% decreased at MEY level compare to the present situation.

Scenario 3

Compared to the current situation (Scenario 0) the differences of economic level were TK138million and TK168million at MEY and MSY level respectively. Under this scenario about 41% change has been shown at MSY level which is really not good news for the fishery economy. On the other hand, harvest level was approximately 10% change compare to present condition. This situation might be occurred or most likely scenario for the Bay.

Scenario 4

The results of the model based on this scenario differ about 20% of effort level (at OA) and average 25% of harvest level at OA, MEY and MSY level from the current scenario (Scenario 0). On the other hand, profit impact is roughly 25% at MSY level compare to the reference situation.

Scenario 5

About 35% lowest harvest at MEY level has been found compare to the current position of Scenario 0 whereas nearly 30% and roughly 32% changed of OA and MSY level has been shown compare to the same situation. However, the profit level was approximately 56% lower from the reference Scenario 0. This situation has been showing slightly bad position than scenario 1, 2, 3 and 4.

Scenario 6

The difference of harvest level were 6248, 9768 and 8288 tonnes at OA, MEY and MSY level respectively compare to the present scenario. On the other hand, effort level has been shown only nearly 10% change from the same situation. However, profit impact is about 10% at MEY level whereas it was negative at MSY level compare to the current situation.

Scenario 7

The comparative higher difference of harvest and profit level have been shown in this scenario from the reference of Scenario 0.The difference of profit level were TK363million at MEY level compare to the current situation. This situation might be worst case scenario for the Bay.

Scenario 8

This is the last scenario and it was the highest change or difference among all the scenarios. The difference of harvest level were 12400, 14362 and 14440 tonnes at OA, MEY and MSY level respectively compare to the current situation and this was the maximum difference . On the other hand, profit impact was about 64% at MEY level compare to the present situation and it was also higher among other scenarios. This scenario might be happen due to tremendous increase of green house gas, carbon-di-oxide and other gas as a result temperature shifted by 5-10 degree Celsius over the next 100 years. It also might be occurred while industrial countries have not come up with any argument or not make any regulation for gas emission.

Finally, comparatively big changes or difference in case of harvest level (OA, MEY and MSY), corresponding effort and profit level have been shown in Scenario 4, 5, 7 and 8. These four scenarios presented changed or difference of profit level of TK159million, TK262million, TK363million and TK408million at MEY level respectively from the present of Scenario 0. In the case percentage level, it was 25%, 41%, 57% and 64% respectively compare to the current situation at MEY level which is interesting and telling that results are very sensitive for the parameter estimations and which has been given the uncertainty involved and it makes the model less reliable and it is the important findings for this study.

5.4 Yield-Climate Interactions

The wide range of interannual variations for the individual species confirms that fishing effort alone does not explain for the variations in catch per unit effort. According to Orensanz (1986) growth, mortality and recruitment parameters are extremely dependent on environmental conditions even between small distances. The particular changes of climate such as water temperatures can directly affect on survival of juveniles and distribution of fish growth (Roessig et al., 2004). Therefore, an assessment and projections about the fishery cannot be made without due consideration of the climatic influences. The output of the surplus production models discussed that the coastal climate or any other change of climate will impact on the production of the fishery. Fishing zones and fish production in the coastal area of Bangladesh are declining gradually over the years and they attribute it to sea level rise, increase of salinity at coastal belt, frequent cyclone and change in the oceanic current pattern (Azad, R,I., 2009). However, yield and climate has an interaction since responses of species to the different environment, a consideration of abundance and dynamics is needed for clarification of the yield-climate relation.

5.5 Coastal climate and interactions with fishery

From October to November there is a second transitional period known as the post monsoon when the majority of cyclonic storms occur which might be caused by global warming. The geographical location and geomorphological conditions of Bangladesh have made the country one of the most vulnerable ones to climate change, particularly to sea level rise (Ali, 1999). At present, the marine and estuarine ecosystem of the Bay of Bengal have been threatened by different types of pollutants which is dumped directly into the ecosystem or washed down through large number of rivers and tributaries. Pollution is the result of climate change as we as tremendous increase of polluting industries. Direct fish kills and the toxic effect on the mortality of post-larvae and juveniles in the nursery grounds (Islam, 2003). Perry et al., (2005) also mentioned that climate change has impacts on marine fish distributions, and observed rates of boundary movement with warming indicate that future distribution shifts could be pronounced. There are multiple and rather complex pathways through which climate change can affect the productivity and distribution of open water fishery resources and their associated livelihood as well as economic linkages.

5.6 Implications for Management and adaptation strategies from climate change

A plan to manage the Bay of Bengal fishery stocks into the future needs to develop. A need for experimental research for fishery resources is the next step. This paper studies just a small part and has been made assumption of the effects of climate change on fish stocks. It still leaves a gap to answer many questions, but only a well-structured research programme may will manage all the uncertainties of this study. For instance, taking a pilot study for a period of time, collecting all the results by the use of experiments on board such as meteorological data analysis for time series and compare the catches or need depth study related to any new method (i.e. GCM) for the fishery. The fisheries management must plan to keep the effort level at a sustainable position as a means to reduce the fishing mortality rate, as this will generate benefit to the whole industry in terms of higher profits. Most importantly, with the current pressure of fish stocks due to environmental conditions of Bangladesh, there is a need to keep a moderate level of effort that will provide less catches and still profitability will outweigh other factors such as high effort and catch. From this study, it will be worthwhile for the management committee for fishery to consider an tremendous increase in effort level and a possible growing in trawling fleets. With the presence of climatic effects in fishery stocks, both biological and economic losses can be expected. The adaptation should also consider such effects once it has been known that climate affects the overall economic benefits and biological parameters. However, Ayers and Huq (2008) noted that changes in temperature and water resources with climate change will result in direct pressure on many climate-sensitive species. The need for adaptation to reduce the effects from climatic change should therefore be of a concern. There are some ways to be adapted with the coastal climate of Bangladesh which maybe include; changes of attitude of the people and its government, long-term strategy, raising awareness, initiative of research and development programs, training and educational programs.

5.7 Limitations of the Study

Theoretical models for prediction of the climate in the sea, impacts on fishery resources particularly in the Bay of Bengal regarding Bangladesh are still unavailable. Assumption of future impacts was based on some scientific literature.

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 climate were excluded. The extent by which these and other climatic factors influence fishing has not been investigated here and should be considered in a future study.

5.8 Conclusion

Major findings from this study is that the fishery is not over exploited may be the result of high effort cost. The study also indicates that effort level could be going up in near future. It is not good news because fishery will be over exploited easily though the fishery is still suitable position because actual catch and effort don't exceed the MSY level . However, increase of effort level could means growth of population, high unemployment rate, demand of fish and fishery products for the country. However, the immediate problem to address in this fishery seems to be reduction of cost of effort, provide alternative employment. The same goes to maximising sustainable yield, while resource rent could not be maximising could not be obtained without significant effort reduction. Furthermore, growth rate and stocking density of the Bay will be reduced by any other climatic change as well as will impacts on economy or profitability under three reference equilibriums (regimes) and climate consequences.

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