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A TIME SERIES ANALYSIS OF MARINE FISHERIES PRODUCTION IN BANGLADESH: THE IMPLICATIONS OF PROPERTY RIGHTS FOR SUSTAINABLE DEVELOPMENT

Md. Saiful Alam

ABSTRACT

Marine fishery in the Bay of Bengal and in the surrounding coastal areas is a highly valued renewable natural resource in the agricultural sub-sector of Bangladesh. It bestows the national economy with ample employments, food security, export earning, and is a safety net for the people who possess little. Its capture fishery Bangladesh in the Bangladesh chapter is placed third at the global level reflecting its economic significance of sustainable use. The essay makes an effort towards a quantitative analysis of marine fisheries development and tries to draw some qualitative implications of fisheries development in Bangladesh. In the time series analysis, it is found that both effort level and investment in marine fisheries must have reached a saturation level. While existing poverty may exacerbate overfishing phenomenon in capture areas, the fishing right arrangements require certain over-hauling including effort-control and the joint conservation practices.

I. INTRODUCTION

Background

Marine fish is not only the best source of lysine and amino acid, which are scantily found in cereals and grains that dominate food production by providing nearly half of the world protein supply (Smith and Wilen 2002), but also a very important contributor to our national economy. This remarkable source of food provides for a significant portion of animal proteins consumed in Bangladesh, and so is the case in other developing regions including South-East Asian countries. Particularly, in our country, apart from being a base for food security, marine fishery is a traditional employer of a huge number of people and remarkable foreign exchange earner. Even though, the scope of marine fishing is restricted to southern marine coastal areas, in aquaculture production', Bangladesh is among the top seven in Asia (FAO 2000) and Bangladesh ranked third in world captures production in 2000 (FAO 2002). Internally also marine fisheries production has apparently marked spectacular growth as did the inland fisheries (see Appendix-A). In spite of these achievements, researchers express doubts that marine fish production might actually be declining over time under the prevailing property right arrangements. In this background, the article conducts a time series analysis of the marine yields using econometric tools, and explores the property right implications of the econometric findings.

The author, currently working in the Ministry of Land, GOB, as an Assistant Commissioner (Land) in Comilla District, acknowledges for the comments and suggestions of Dr. E.H. Petersen, Dr. Tom Kompas and Dr. Satish Chand in using relevant econometric concepts and applications, while he was undergoing foreign training as Assistant Secretary (O.S.D.) of GOB in Canberra, and drafted the paper under their inspiration.

Organization of the Paper

Data use from relevant literatures on marine fisheries, national statistical records and international sources paved the way for analyzing a time series analysis of the marine fisheries growth in the agro sub-sector, using econometric tools and concepts applied in statistical package STATA with a view to estimating relative weights of the relevant variables of marine fisheries development in Bangladesh. And then its finding and the popular concepts of resource and environmental economics are utilized in delineating property right implications of sustainable growth lightly exemplifying the case of *Hilsa* fisheries. Regulating the rights to catches, need for reshaping the institutional arrangements in the Bay of Bengal, prevailing inadequacy of the government under individual transferable quota (ITQ) are explored with a view to touch on the sustainability question of marine fisheries resources of our country.

II. DATA SOURCES AND METHODOLOGY

Marine fishes are caught in the Bay of Bengal (see Appendix-B depicting EEZ of the country) over approximately 16,456 square nautical miles. Therefore, Bangladesh participates in exploiting global marine resources through only this Bay, which is an expanse linked to the Indian Ocean, though FAO categorises Bangladeshi sea harvests as part of the Asia-Pacific region. Marine catches mainly include fin-fishes and crustaceans (prawns). Fish is harvested by both mechanised and non-mechanized boats, modern gear-nets. Also fishing methodology, level of effort and weather condition markedly influence yearly catches. This section makes an attempt to estimate temporal changes in fish output caught from the sea relative to inputs-use after constructing a theoretical framework and specifying the model.

Theoretical Framework

The essay considers number of fishing crafts and effort-days spent (Kirkley *et al* 1995 and Sharma & Leung 1999) as key inputs to marine fish production between the period 1972 to 2000. Due to predominance of non-mechanized boats, available statistics on gear units are not used. Following Staples and Maliel (1994), a time trend is also incorporated to capture stock effects over this duration (Kompas, Che and Grafton, 2002). The production function is thus envisaged as

$$F = f(I, E)$$

where F = marine fisheries production in metric tons

I = fishing crafts in numbers

E = actual effort days

The exact figure on other material inputs, such as, fuel is not readily available and so is proxyed by the variable E, which represent actual effort days of equivalent fish trawl. Currently, no up-dated data is available on stock abundance or recruitment for inclusion in the function.

Model Specification

For the purpose of time-series analysis, the following Cobb-Douglas functional form is chosen to check long-term relative importance of the inputs, output elasticity and possible variations in stock-size:

$$F_t = AI_t^{\beta 1}E_t^{\beta 2}$$

or, $lnF_t = lnA + \beta_1 lnI_t + \beta_2 lnE_t$

where, A = Solow residual

$$\beta_1 = \partial\, lnF_t/\partial\, lnI_t = \partial\, lnF_t/\partial F_t \times \partial F_t/(\partial\, lnI_t/\partial\, I_t)\times 1/\partial\, I_t = \partial F_t/\partial\, I_t \times I_t/F_t$$

= elasticity of yield with respect to input I_t

$$\beta_2 = \partial\, lnF_t/\partial\, lnE_t = \partial\, lnF_t/\partial F_t \times \partial F_t/(\partial lnE_t/\partial E_t)\times 1/\partial E_t = \partial F_t/\partial E_t \times E_t/F_t$$

= elasticity of yield with respect to input E_t

Our purpose is to find productivity of fishing efforts and to see how it is affected by changes in input-efforts ratio. Additionally, if we assume constant returns to scale meaning $\beta_1+\beta_2 = 1$, the production function can be rearranged in the following way:

$$lnF_t - lnE_t = lnA + \beta_1 lnI_t + \beta_2 lnE_t - lnE_t$$

$$or,\ lnF_t - lnE_t = lnA + \beta_1 lnI_t + (1-\beta_1)lnE_t - lnE_t$$

$$or,\ ln(F_t/E_t) = lnA + \beta_1(lnI_t - lnE_t))$$

$$or,\ ln(F_t/E_t) = lnA + \beta_1(lnI_t/E_t)$$

The statistical model thus takes the shape of

$$ln(F_t/E_t) = a + \beta_1(lnI_t/E_t) + \beta_2 t + u_t$$

where $a = lnA$ and u_t is the normally distributed random error term with zero mean and variance σ^2_u. $\beta_2 \times 100$ shows percentage point change in catches over time. Incorporation of such a linear time trend can be justified on grounds of (i) small number of observations and (ii) $ln(F_t/E_t)$ and (lnI_t/E_t) being integration of the same order (Otto and Voss 1994), which is indeed the case as we will see later.

Data Sources and Adjustments

The time series data on marine yields, fishing crafts, effort-days are collected from different sources; the main variables of interest are presented in Appendix-C. The Statistical Yearbook of Bangladesh (various issues) remains the key data source for dependent variable F_t and explanatory variable I_t. The data on E_t is calculated from information compiled by Khan and Latif (1997) for the years up to 1991. For the years from 1992 to 2000 figures are proxyed by 5-year moving average of preceding years. Given the nature of the record-keeping of a developing sub-sector, vessel-specific statistics could not be accessed. Moreover, only 29 observations were considered because separate data on Bangladesh statistic were available since 1972 when this country became a new state.

Econometric Procedure

STATA 7.0 was used to run the program. First, stationarity of the variables is checked, because in the presence of unit root, OLS (ordinary-least-square) estimates might be spurious (Griffith, Hill and Judge 1993). So the Dickey-Fuller test for unit root is conducted in the following way:

Unit-root test for the regression equation, $ln(F/E)_t = \alpha_1 ln(F/E)_{t-1} + \mu_t$;

$\mu_t \sim N(0, \sigma^2_\mu)$

Hypotheses: $H_o : \alpha_1 = 1$ (unit root exists)

$H_a : \alpha_1 < 1$ (no unit root)

If $|DF_{cal}| < |DF_{cr}|$, we accept H_o, which means that unit root exists and data variable is non-stationary at relevant level of significance.

Unit-root test for the regression equation, $ln(I/E)_t = \alpha_1 ln(I/E)_{t-1} + \mu_t$;

$\mu_t \sim N(0, \sigma^2_\mu)$

Hypotheses: $H_o : \alpha_1 = 1$ (unit root)

$H_a : \alpha_1 < 1$ (stationary)

By the similar reasoning, if $|DF_{cal}| < |DF_{cr}|$, we accept H_o meaning that unit root exists and data variable is non-stationary at 1%, 5%, 10% level of significance.

In Stata-7 output, independent variable $ln(I_t/E_t)$ is found stationary (since $|DF_{cal}| > |DF_{cr}|$, i.e., $|4.11| > |DF_{cr}|$ at 1%, 5%, and 10% level of significance) we had to reject H_o: $\alpha_1 = 1$ in favour of $H_a : \alpha_1 < 1$, which means that unit root does not exist and data variable is stationary. The dependent variable $ln(F/E)_t$ is also found stationary as $|DF_{cal}| > |DF_{cr}|$, i.e., $|4.216| > |DF_{cr}|$ at 1%, 5%, and 10% level of significance, and H_o: $\alpha_1 = 1$ is rejected in favour of $H_a : \alpha_1 < 1$, confirming stationarity of $ln(F_t/E_t)$. This is cross-checked by plotting residuals which indicated no multico-linearity. The Durbin-Watson test (Durbin 1970) also signalled no serial correlation. Then $ln(F_t/E_t)$ is conveniently regressed on $ln(I_t/E_t)$ in OLS-way following Enders (1995).

III. TIME SERIES ANALYSIS OF MARINE FISHERIES PRODUCTION

Econometric Results

Computer simulation in STATA 7 has yielded the estimated values of the parameters presented in Appendix-D. The summary of the estimated relationship between $ln(F_t/E_t)$ and $ln(I_t/E_t)$, thus, can be presented as-

$$\hat{Log}(Yield_t/Effort_t) = 228.93 + 1.91\ Log\ (Vessel\text{-}Input_t/Effort_t) - 0.1113\ (Time)$$

(SE:19.541) (SE: 0.396) (SE: 0.01)

Economic Interpretation

The first feature of the results is that yield per unit of effort is positively linked to the ratio of vessel-inputs and effort. In elasticity terms, one percent increase in crafts-effort ratio causes 1.91% rise in catch per unit of effort day. It means marine fish productivity could be increased by engaging more fishing vessels. This estimated coefficient of $ln(I_t/E_t)$ is quite significant (having a zero *p-value,*) and may be interpreted as bearing the implication of ample scopes in marine fisheries investment. But the figure-6 depicting time-plot of $ln(F_t/E_t)$ shows that the yield-effort ratio had actually fallen over time up to the year 1988 and remained at same rate and then culminated showing a slightly upward trend. Since catch per unit of effort has been decreasing through time, this may be an evidence for economic over-exploitation of marine fisheries.

Figure 1: Plot of ln(f/e) against time (yt)

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          +-------------------------------------------------------------+
            1972                      Yt                             2000
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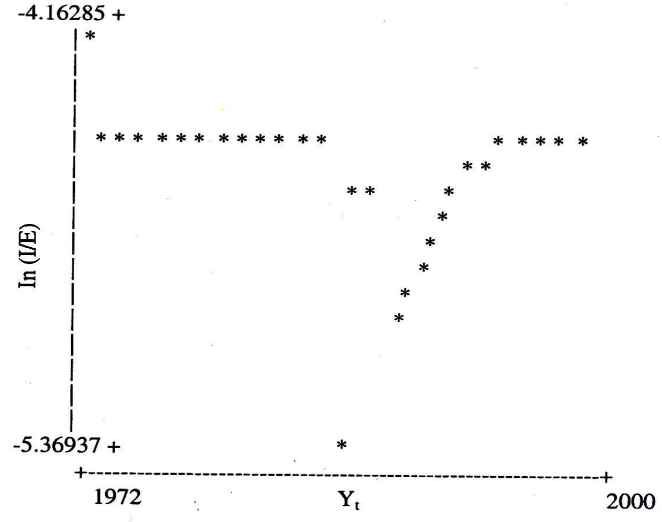
Similarly, the trend of $ln(I_t/E_t)$ depicted in figure-2 also had fallen up to the year 1988 and then began rising until 1996, thereafter remained unchanged till the end of the observation period.

Together, these pictures demonstrate that productivity of marine catch per unit of effort could be augmented by raising capital-effort ratio either by reducing the frequency of trawl-days or by adding more gear-units to fishing capital – essentially the same result consistent with the regression outcome. But as far as the sustainability question is concerned, in such a case, increasing investment may lead to pushing harvest to open access level. This is the popular `open access problem' which must be curbed by appropriate policy measures.

The second observation is that the productivity of marine catch has actually registered a negative growth rate over the 29-year period in question. This significant 11.13% overall fall in marine fisheries growth might be a reflection of the declining stock level – so including a trend to capture stock-effects through time (Kompas 2002a) is apparently justified. Even if it is not true, this negative time-variant effect might have ensued from too much capacity, i.e., over-utilization of existing capacity.

Figure 2: Plot of ln(i/e) against time (yt)



IV. PROPERTY RIGHTS IMPLICATION

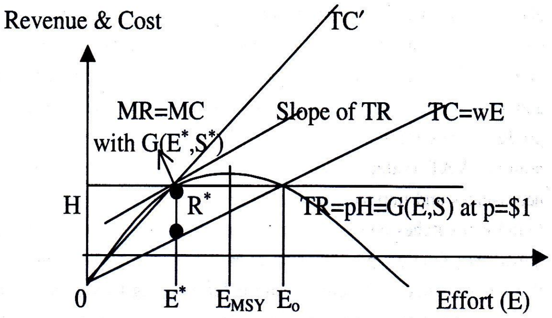
Marine Fisheries

Resource economists contend that property right structures for the exclusive economic zones that each nation having sea frontier has been granted, is quite well-defined so there are a great deal of advantages of the off-shore fishing industry for exploiting the tenured rights into concrete economic gains (Petersen, 2002b). This, however, seems partly true in the changing perspective of global economy. For example, *The Economist* (May 23, 1998) observed that number of fishermen as well as fish farmers has been more than doubled in the last 25 years; moreover, Governments have used subsidies encouraging people to work and to invest in fisheries, especially after territorial waters were extended to 200 miles in 1982. That is, limiting access to resource, use of appropriate control mechanisms and setting up reserves to preserve habitat have become central focus of fisheries development. In this background, we discuss the implication of property rights on fundamentals of marine fisheries of Bangladesh in terms of theory and practice.

Position of Bangladesh

Like elsewhere in the globe, open sea capture fisheries in Bangladesh had long been taken for granted as the gift of nature and unregulated fishing continued until recently when it became clear that restricting property rights of harvesting is a *sine qua non* for conserving resource and maximizing fisheries rents. In this respect, popular fisheries economic theory contends that both input and output control mechanism could be made to affect access and harvesting, though these traditional controls, even if rigorously applied on fishing rights in the Bay of Bengal, may not yield desired output. To see this, the study performs a brief review of standard textbook analysis (Common 1996, Hartwick & Olewiler 1986) of merits and demerits of traditional control devices.

Figure 3: Interrelation of Harvest, Effort, Cost and Revenue



Regulating Rights to Catches

As per popular theory, let's denote F(S) as the instantaneous growth rate of fish species, H as harvest rate which is again a function of effort (E) and stock (S), i.e. H=G(E,S), TR as the fish-revenue being equal to H when fish-price 'p' is normalized to $1, TC as the total cost of fishing equal to *w*E, '*w*' being the unit cost of effort (Figure 3). The maximum social welfare then can be expressed as $MSW=pG(E,S)-wE + \lambda[F(S)-G(E,S)]$, the first-order condition for maximization of which gives $G_E + (G_E G_S)/[F'(S)-G_S] = w/p$ where w/p is the real wage, G_E is the marginal product of effort, G_S is the marginal product of harvest, λ being the shadow price. The term $(G_E G_S)/[F'(S)-G_S]$ is the negative 'stock-effect' (Hartwick &

Olewiler 1986) which can be internalised by controlling input, e.g., regulating effort level (by taxing at the money rate of $(G_E G_S)/[F'(S)-G_S]$ or setting effort quota to the left of E_{MSY} (maximum-sustainable-yield effort), say, at E^* in the above diagram where marginal revenue (MR) of fishing is equivalent to marginal cost (MC) of effort at efficient harvest level and maximized fisheries rental R^*(=TR-TC).

On the other hand, if output is controlled (by setting quota on harvest at H, *a priori*), harvest is restricted but that would lead to excessive use of effort E^o (since at H, two steady-state effort levels are possible, see Hoy *et al*, 1996) and quick depletion of stock with probable rise in production cost and fish-price (Gallastegu 1983, Agnello & Donnelley 1976). Moreover, optimal tax on catch is difficult to ascertain with the additional concern that harvesters get incentives to evade tax by hiding catch. The main disadvantage of input control is that all components of efforts may not be covered by regulation. For example, as Tom Kompas (2002a) showed, if 'A-unit' (a measure of engine and vessel size) is controlled, fishers may increase gear-length leading to higher costs which is allocatively inefficient, i.e., use of wrong input-proportion, and may be technically inefficient as well, i.e., over-use of inputs (Forsund *et al* 1980).

Institutional Arrangements in the Bay of Bengal

If we examine economically the Bay of Bengal chapter of Bangladesh in the lights of above arguments, we find, however, slightly different picture. Roughly 17,350 fishing boats having approximately 24,000 gear units operate in the fishery – only 67 are modern crafts, almost 60% are artisanal or non-mechanized ones. Government gets fees by licensing inputs and encourages private sector to invest in harnessing marine resources because marine produce earns foreign exchange for the economy, at least in the short run. Also, existing nominal VAT (value added tax) on catch indicates actually less regulation than reality necessitates and implied subsidy. In the time series analysis of marine fisheries growth, it is found that catches and capital inputs are positively correlated but catch-yield ratio has gone down over time coupled with an overall negative growth rate, which means investment in fleets is saturated and there is reasons for stopping Government's implicit subsidy in further marine fleets investment. This provides a strong case for regulating effort. But given the shortcomings of the traditional control devices, as reviewed previously, economic activities in marine fisheries could be better managed under Individual Transferable Quota (ITQ). It is increasingly advocated that ITQ, which is a proportion of the total allowable catch (TAC), can put a check on the excess-fishing (by setting TAC=S^* and E=E^* in the above diagram), while at the same time can discourage new investment in catching more fishes. In the market of numerous semi-mechanized fishing fleet, ITQ could work better and ensure twin benefits, i.e., earning additional revenue and allow healthy regrowth, particularly, of *Hilsa* fish by conserving species. Moreover, creating quota and increasing access fee there are ample scopes for fisheries infrastructure development (Petersen 2002a).

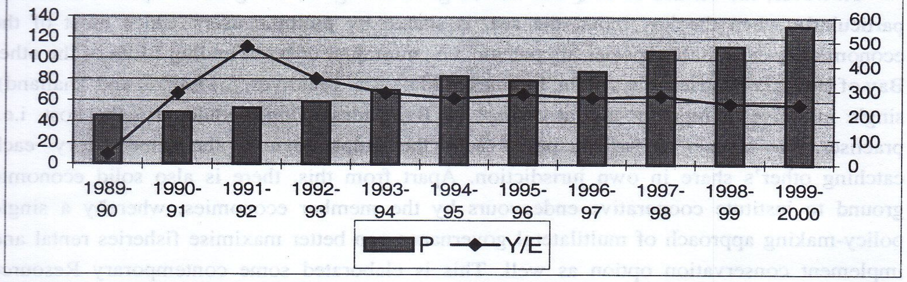
Some Inadequacy of Government under ITQ

However, the virtues of ITQ can not be good enough to bring about optimal outcome, particularly when the key input, the sea, is shared by multiple users. Since most of the economically exploitable species are pelagic, i.e., migratory or transcending EEZs of the other Bay of Bengal countries (e.g., India, Indonesia, Malaysia, Maldives, Sri Lanka, and Thailand), single initiative at input or output control by Bangladesh alone would turn the host, i.e., practiser, into a loser as we can perceive by the simple logic of the game theory- each catching other's share in own jurisdiction. Apart from this, there is also solid economic ground to institute cooperative endeavours by the member economies, whereby a single policy-making approach of multilateral governance can better maximise fisheries rental and implement conservation option as well. This is elaborated some contemporary Resource Economists, for example, the model of Satish *et al* (2002) showed that regulating property rights as a management instrument through stake-holders' joint body can produce better economic outcome. Such model also figured out that joint cooperation in managing migratory and straddling fish stocks is required under the UN fish stocks agreement. One immediate example can again be cited for *Hilsa* which holds a good case for multi-lateral conservation under such frame-work as lightly focused below.

Hilsa Fish of the Bay: ITQ or Joint Control?

Hilsa, a gifted fish of our land and national delicacy, is the only one of the marine varieties, which is caught in rivers and heavily overfished. This is identified as the largest estuarine fishery in the world and an important ingredient of food in Bangladesh (CSIRO, 2003). It is also known to be culturally very important fish in Indonesia (Sumatra) and Malaysia (Sarawak). In all cases, it can readily be shown that even ITQ as an optimal property right instrument can not suffice to ensure sustainable catch of such an estuarine migratory fisheries. Licensing out the *Hilsa* catching rights over the years has caused excess exploitation and crowding-out phenomenon. For example, Figure 4 below depicts that increasing *Hilsa* prices per kilo invited more efforts and gradual fall in catches (also see Appendix-E) indicating quick depletion of stock and eroding prospect of ITQ in its output control. Therefore, it might require appropriate effort control. Since it is a pelagic species, multilateral governance by the *Bay of Bengal* countries can provide alternative way-out and save this species from overfishing and extinction. Such framework might involve the possibility that common law and strict enforcement in signatory countries would exert a check on indiscriminate catching in respective sweet waters during spawning season and converse matured stock in common marine waters.

Figure-4: Trend in *Hilsa* Price (P) and Yield-Effort Ratio (Y/E)

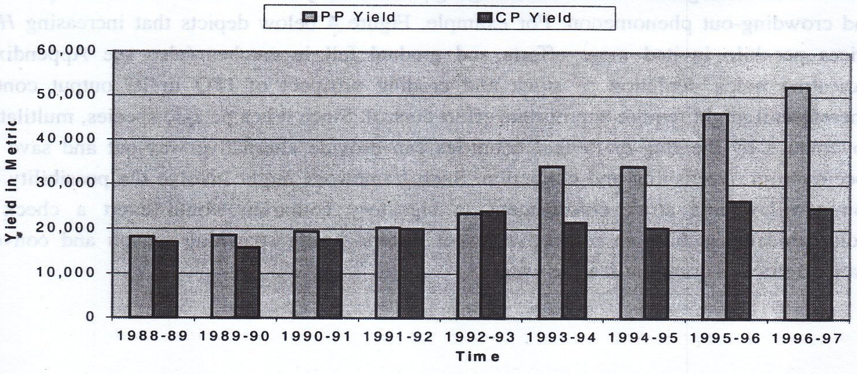


Source: Compiled from the *Monthly Statistical Bulletins of Bangladesh* (1989-2000) using averaged effort-estimates of *Khan and Latif* (1997).

Contrast with Culture Fisheries

Unlike open access fisheries, most cultured fisheries are privately owned and exploited, as a result, fisheries rent is maximised, therefore, need not require joint regulation, or arranged property rights. Since the maximum sustainable yield is obtained here through proper stocking-nursing-harvesting process, there is no stock-effect as is common in open access capture fisheries. Private-owners take care of the fishing grounds for there own profitability leaving no congestion effects either, reflecting full virtues of monopoly property rights in fisheries. This is evident from the shrimp production under different institutional arrangements, as shown in Figure 5.

Figure 5: Shrim Production under Different Ownership Arrangements



Source: Constructed from the Statistical Year Book of Bangladesh, Various Issues.

As Figure 5 shows, shrimp, which is both farmed in coastal areas and captured from the open bay, has registered different growth marks under different ownership arrangements. As we can easily ready off, the private property (PP) yield is more than doubled in the periods 1988 - 1997, whereas common property (CP) yields have most of the time dwindled around 20,000 metric ton annually. The upshot is that, when the fish stock is non-migratory, as in the coastal areas, it is economically better off to leave property rights in fishing in single body and no joint regulation, whereas, for valuable migratory fish species, multilateral conservation can prevent rent dissipation and promote economic use. Even shrimp resources in open capture areas have no future because of its unsustainable harvest. In such case, property rights in the individual transferable quota could prove to be best option for the time being.

V. CONCLUSION

The time series analysis of marine fish production shows that yield-effort ratio has fallen through time indicating possible economic over-exploitation. Since input-effort ratio has also declined by that period, it might not constitute a case for raising or subsidizing new investments as it may push harvest beyond the maximum sustainable yield toward the open access level. This point can be supported by overall negative growth rate in marine yield of 29 years.

Both `stock effects' and `congestion effects' are found to be exacerbated by the existing property entitlements in marine fisheries of Bangladesh. Standard text-book arguments of effort control under ITQ mostly hold with coastal capture fisheries with some limitation and there is a strong case for joint effort towards conserving *Hilsa* resources of the Bay of Bengal.

Lastly, in tune with *The Economist* (Decl, 2001), it can be concluded that the future of fish would depend on better management and aquaculture rather than capture practice. For this reason, limiting access to resource by introducing ITQ, putting resource at the private hands in practice areas, stopping subsidy to marine investments and setting up of common reserves for engendered species under joint regulation are indispensable in this agricultural sub-sector development in Bangladesh.

Limitations

Few limitations need to be acknowledged. First, econometric models are kept as simple as possible, whereas reality might require inclusion of more explanatory variables. This is primarily due to limited data availability on this sub-sector of agriculture. The quality of used data on at least one important variable (effort level) might also be given a second thought as it is calculated in a too simple way. And lastly, as vessel-specific data involving more time spans could not be utilized in this paper, there remains possibility of some `statistical bias' in the output. Nevertheless, it is hoped that the broad implications could be drawn without affecting the envisaged objectives.

Fote Notes

1. The term 'aquaculture' is limited to mean fish-farming for our purpose, though it generally includes all fish, crustacean, mollusc (FAO 1998) and culturing of other aquatic plants. Also 'marine fish' would imply fish found or produced and sustained by sea-water and connote 'mari-culture' (cultivation of fish for food) in narrow sense following 'The Australian Oxford Dictionary' (1999).
2. Several species of tuna and skipjacks, few species of mackerels, sardines, anchovies are available in EEZ (Khan and Latif, 1997).
3. Under these arrangements, each fishers are given permission to harvest a certain tonnage of fish but these rights can be traded between fishers, and holders have incentive to catch at lowest possible costs and to sell quota to others if they can fish at lower cost (Smith 2003).
4. Satish *et al* (2002) described aggregate catch of the fish species needing multilateral governance by the Cobb-Douglas production function $H = C^{\alpha}N^{\beta}S(\kappa)$, where, H denotes the total *Hilsa* catch, C as harvesting country's capital stock, N signifies the number of fishers and S is the steady-state biomass of *Hilsa* to be sustained by appropriate policy instrument κ such that $S_{\kappa} > 0$. Individual fisher's production is captured by the intensive form equivalent $h = \kappa\chi^{\alpha}S(\kappa)$ where χ is per capita capital being too small to impact S. Individual fisherman receives after-tax profit $\pi= (1-\kappa)h-r\chi$ assuming unit product price and r as the return to capital. The first-order condition for profit maximization leads to the steady-state stock of capital $\chi^{*}=[\alpha(1-\kappa)r^{-1}S(\kappa)]^{1/\beta}$. If the single regulator acts as Stakelberg leader affecting fishing effort through of choice of κ on H, then the steady-state rent accruing to the regulator (consequently to all parties) is $\Pi = \kappa N\chi^{\alpha}S(\kappa)$. Setting $\alpha=0.5$ and assuming S_{κ} a constant $(=\mu)$, we get the condition of revenue maximization as $d\Pi/d\kappa=0.5r^{-1}[N-(N+2r-2\mu NS)\kappa-2\mu NS\kappa^{2}]=0$ yielding $\kappa^{*}= [-(N+2r-2\mu NS)+ \{(.)^{2}+8\mu N^{2}S\}^{0.5}/(4\mu NS)$. Satish *et al* (2002) concluded that single policy-maker, e.g. joint watch-dog, can effectively control the choice of κ^{*} in such a way that both long-term rent is maximized and species is sustained.

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APPENDIX-A

Production of Inland and Marine Fresh Fish by Main Varieties:

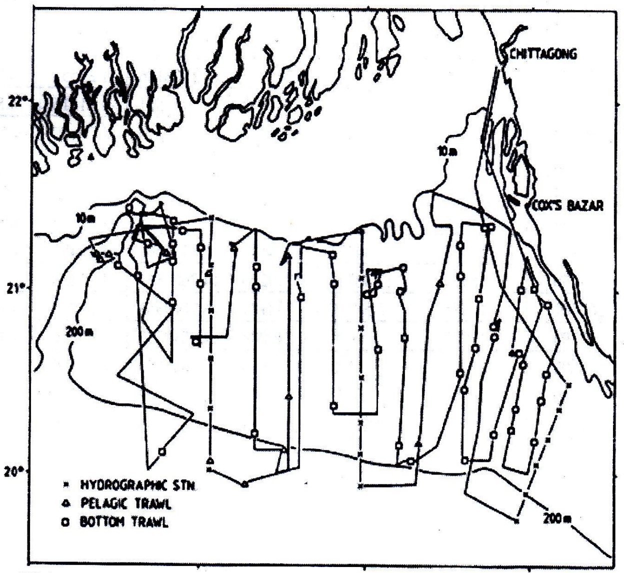
(Thousand Metric Tons)

Fish Sources	Type of Fish	1994-95	1995-96	1996-97	1997-98	1999-2000
Inland Fish Total:		908	987	1079	1190	1243
1.	*Rui, Katla, Mrigal*	174	188	206	228	340
2.	*Ghania, Kalbasu, Katla*	11	11	12	14	5
3.	Siliver, Common, Mirror and Glass Carp	55	60	65	72	150
4.	*Rita, Boal, Silon, Aor, Bacha*	29	32	35	38	35
5.	*Shol, Gazar, Taki*	61	67	73	80	44
6.	*Koi, Shingi, Magur*	65	70	77	85	63
7.	*Hilsha*	84	92	100	111	74
8.	Shrimp	93	100	110	122	132
9.	other	336	367	401	441	420
Marine Fish Total		265	279	294	274	309
Grand Total		1,173	1,266	1,373	1,464	1,552

Source: Directorate of Fisheries, Government of Bangladesh, 1998.

APPENDIX-B

The Bay of Bengal: Bangladesh Chapter : Exclusive Economic Zone



Source: **Saetersdal, G., G. Bianchi, T. Stromme (1999)**

APPENDIX-C

Main Time-Series Variables.

Year	Marine Yield (M.T.)	Inputs Used (No. of Crafts)					
Yt	F_t	I_t	1nF	1nI	1nE	ln(F/E)	ln(I/E)
1972	95000	110	11.46163	4.70048	8.86333283	2.598299	-4.16285
1973	87000	210	11.37366	5.347108	9.79009487	1.583569	-4.44299
1974	88000	297	11.38509	5.693732	10.1359476	1.249145	-4.44222
1975	89000	1021	11.39639	6.928538	11.3706474	0.025744	-4.44211
1976	95000	1026	11.46163	6.933423	11.3756385	0.085994	-4.44222
1977	100000	1076	11.51293	6.981006	11.4228695	0.090056	-4.44186
1978	110000	1126	11.60824	7.026427	11.4686182	0.139617	-4.44219
1979	118000	1226	11.67844	7.111512	11.5536835	0.124756	-4.44217
1980	122000	1326	11.71178	7.189922	11.6320765	0.0797	-4.44215
1981	125000	2024	11.73607	7.612831	12.0548194	-0.31875	-4.44199
1982	130000	2085	11.77529	7.642524	12.0846618	-0.30937	-4.44214
1983	141000	2153	11.85652	7.674617	12.1166948	-0.26018	-4.44208
1984	165000	3420	12.0137	8.137396	12.5792556	-0.56555	-4.44186
1985	187563	3807	12.14187	8.244597	13.6139695	-1.4721	-5.36937
1986	207401	9741	12.24241	9.184099	13.7454035	-1.50299	-4.5613
1987	217579	9642	12.29032	9.173884	13.7520317	-1.46171	-4.57815
1988	227582	10385	12.33527	9.248118	14.1708186	-1.83555	-4.9227
1989	233281	11385	12.36	9.340052	14.1751551	-1.81516	-4.8351
1990	239063	L2385	12.38448	9.424241	14.1794729	-1.79499	-4.75523
1991	241008	13385	12.39259	9.50189	14.1837721	-1.79119	-4.68188
1992	244474	14385	12.40686	9.573941	14.1880529	-1.78119	-4.61411
1993	250092	15385	12.42958	9.641148	14.1923155	-1.76273	-4.55117
1994	253144	16385	12.44171	9.704122	14.19656	-1.75485	-4.49244
1995	264750	16485	12.48654	9.710206	14.2007866	-1.71425	-4.49058
1996	269702	16885	12.50507	9.734181	14.2049953	-1.69992	-4.47081
1997	273704	16985	12.5198	9.740086	14.2049953	-1.68519	-4.46491
1998	295200	17085	12.59541	9.745956	14.2049953	-1.60959	-4.45904
1999	296920	17385	12.60122	9.763363	14.2049953	-1.60378	-4.44163
2000	307340	17385	12.63571	9.763363	14.2049953	-1.56929	-4.44163

APPENDIX-D

Results of Time-Series Analysis

Number of obs =	29
F(2, 26) =	89.35
Prob > F =	0.0000
R-squared =	0.8730
Adj R-squared =	0.8632
Root MSE =	0.43971

Source	SS	df	MS
Model	34.5485649	2	17.2742824
Residual	5.02693278	26	0.193343568
Total	39.5754976	28	1.41341063

$\ln(F_t/E_t)$	Coef.	Std. Err.	t-ratio	P>|t|	[95% Conf. Interval]
$(\ln I_t/E_t)$	1.90728	0.3959676	4.82	0.000	1.093357 2.721203
time	-0.1113014	0.0099949	-11.14	0.000	-0.13184623 -0.0907566
_cons	228.9296	19.54107	11.72	0.000	188.7623 269.0968

APPENDIX- E

Trend in *Hilsa* price and its yield/effort ratio

Year	Price (taka per kg)	Yield/Effort
1989-90	45.57	39
1990-91	48.69	286
1991-92	52.89	477
1992-93	59.16	347
1993-94	70.28	289
1994-95	83.58	267
1995-96	79.93	285
1996-97	88.09	271
1997-98	107.88	278
1998-99	112.45	247
1999-2000	131.6	243

Source: Data on price and yield are compiled from the Monthly Statistical Bulletins of Bangladesh (1989-2000). Yield/effort ratio is calculated using averaged effort-estimates of *Khan and Latif* (1997).