Chapter 3

Estimation of Bioeconomic Parameters of Trawl Shrimp Fishery in Bangladesh

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3.1. Introduction:

The optimal allocation of renewable resources like fishery over time can be formulated as a non-linear dynamic optimization problem. In such problems, the common objective is to maximize some measures of net economic value, subject to dynamics of the harvested resource and any other relevant constraints, The solution to the dynamic optimization of a resource would be to evolve a schedule or .time-path indicating the optimal amount to be harvested in each period. The whole system depends upon a few specific bioeconomic parameter values. Economists are often faced with the problem of determining parameters associated with such resource stock dynamics. These parameters are biological and economical. The biological parameters are, namely, biomass level (x), intrinsic growth rate (r) and carrying capacity (K). The economic parameters are, namely, demand parameters, cost parameters (i.e. slope and intercept of respective functions) and catchability co-efficient (q).

In case of trawl shrimp fishing in Bangladesh, resource stock dynamic models had not been applied so far for the lack of estimation of such values. Instead of time series data of biomass levels, we have occasional estimations of stock at different point of time by different researchers like West (1973), Rashid (1983), Penn (1983), White and Khan (1985) and VanZalinge (1986). Estimated values are not only discontinuous in time but differ significantly with each other (Table 3.2). Because of this lack of time series data on shrimp biomass level, the important parameter *'intrinsic growth rate (r)'* has also not been estimated. However, two sets of data related to trawl shrimp fishing of Bangladesh i. e. standardized fishing effort and total harvest are available for the period 1981-1982 to 1997-1998, though the said operation had been commenced from 1972-1973.

In this chapter, we have attempted to estimate the annual expected shrimp stock level of Bangladesh by applying the method of estimation of the biomass of demersal stock in tropical zone on the basis of marine data. We, on the other hand, estimate the catchability co-efficient from the available data series of effort and harvest. This calculated value of catchability co-efficient then used to obtain predicted harvest level on the basis of biomass levels of shrimp estimated by us. Then a comparison would be made between the actual annual harvest levels (h) and the predicted harvest levels (h'). The close proximity of predicted values with that of actual values can, therefore, be an indirect verification of the accuracy of estimated biomass levels. Once we have a reliable stock level, the estimation of intrinsic growth rate (r) is also possible and seems to be dependable. We will estimate the demand parameters for three different types of demand functions and try to comprehend one that is the most compatible for the market for Bangladesh trawl shrimp. Using the cost data for Bangladesh trawl catch, parameters of cost function are ascertained. Values of all these parameters will make the formulation and application of non-linear dynamic optimization model for Bangladesh trawl shrimp fishery feasible. The solution of this non-linear dynamic system can determine steady state that indicates the condition of maximum benefit, ensures the long run sustainability of the resource and excludes the possibility of depletion due to overexploitation.

Sources of data: We have used published data of (i) BOBP (1993; 1997) and (ii) Department of Fisheries (DOF, 2000), Bangladesh, for the time series data of harvest and effort for the period 1981-1982 to 1997-1998. Due to the unavailability of time series data on dock-price of commercially exploited trawl shrimp, we have used the published data of EPBB (Export Promotion Bureau of Bangladesh) for time series data of exported shrimp price. The data from the sample survey made by Khan and Hoque (2000) are used for the estimation of cost parameters. FAO (1984) is also used for other necessary data.

3.2. Estimation of Biological Parameters:

Unlike non-renewable resource, any renewable resource is regenerative in nature. In case of fishery, it is the biological property of the resource, which gives this special character to the resource. It is, therefore, obvious that any optimization model should incorporate this biological regenerative property in its formulation. Moreover, because of its time dependent nature, this property makes the formulation dynamic. Though the resource's biological properties depend on many environmental factors and most often these factors are exogenous, some of the biological parameters are incorporated in the optimization formulation with the implicit assumption that those exogenous factors, at least on the average, will remain stable. The following are the parameters normally included in the formulation and biological in character subject to certain environmental conditions:

(a) Level of biomass stock (b) Environmental carrying capacity or saturation level
(c) The intrinsic growth rate.

3.2.1. Biomass Level of Shrimp:

Method: We attempt to estimate annual expected shrimp stock of Bangladesh by applying the method suggested by Pauly for demersal stock in tropical zone subject to specific characters of marine area and trawler.

Stock assessment in the tropics is generally perceived as more difficult than in temperate waters. Pauly (1984) suggested a model for estimation of the biomass of demersal stocks. The model is applicable where the sea bottom is smooth for trawling. Trawl shrimp fishing zone of Bangladesh appears to be very smooth with very few obstacles to bottom trawling (Mustafa and Khan, 1993; Khan *etal,* 1997), Accordingly, the standing stock size can be obtained from the following relationship as suggested by Pauly:

$$x = \frac{c/f \cdot A}{a \cdot y_x} \qquad \textbf{(3.1)}$$

where,

c/f = catch effort ratio during the harvest period,

A = total area under consideration,

a = area "swept" by the net during one unit of effort, and

y = proportion of fish in the path of the gear that are actually retained by the net.

The surface swept by the gear during one unit of effort is computed from the expression

$$a = t.\ v.\ l.\ y_2 \qquad (3.2)$$

where,

t = time spent in trawling,

v = velocity of the trawler over ground when trawling,

/ = length of the trawl's head rope, and

y_2= a fraction expressing the width of the area swept by the net divided by the length of the head rope.

From the equations (3.1) and (3.2) we get the following equation:

$$x = \frac{c/f}{t.\ v.\ 1.\ y_1\ y_2} A \quad (3.3)$$

Values of the dependent variables and constants in the equation (3.3): Penn (1983) and West* (1973) estimated 5,180 square kilometer as the effective shrimp fishing area off Bangladesh. Hence we set the value of A at 5,180 square kilometer for our purpose.

In Bangladesh, two shrimp trawlnets of the same size are operated from outriggers on either side of the vessel. Each net has a head rope of 15.2 meter and a ground rope of 18.6 meter. The codend meshes are 45 millimeter. The gear operates at a speed of 3 nautical miles per hour by a 900-horse power trawler of 32.4-meter length (Mustafa and Khan, 1993). in equation (3.3), the time spent on trawling is given by, 't'. This T is the fishing time. Time spent on trawling 't' being standard shrimp day (not normal day) does represent time spent on trawling and when multiplied with v, I and y_2 (as in equation 3.2) gives us the swept area. As the swept area 'a' is defined as 'area swept by the net during one unit of effort,' T is set to be equal to one standard shrimp day. Hence, the unit of v, represents the velocity, converted to km/day for dimensionality. We have, therefore, v = 3 nautical miles/hour = 133.2 km/day, / = 0.0152 km, t = 1 standard shrimp day for the purpose of our estimation.

In South East Asian waters, the value of y_1 = 0.5 is commonly used (Isarankura, 1971; Saeger era/., 1976; SCSP, 1978) and there are some evidences that this value might in fact be very realistic (Pauly, 1979). Hence we assume that y_1 = 0.5.

Again, in South East Asian waters, values of y_a ranging between 0.4 (SCSP, 1978) and 0.66 (Shindo, 1973) have been used. However, 0.5 possibly being considered as the best compromise (Pauly, 1979), we set y_2 at 0.5. Finally, therefore, values of different dependent variable and constants used in the equation (3.3) are as follows:

Parameters	Values
A	5,180 sq. km.
t	1 Standard shrimp day
V	133.2 km/day
1	0.0152 km.
Vi	0.5
V2	0.5

* The exact value 5,180 sq. km. is actually given by Penn. West mentioned the area as around 5,000 sq. km.

Estimated Results: Substituting these values in equation (3.3), we estimate biomass level (x) of shrimp, in the zone exclusively used by the Bangladesh for commercial exploitation. Accordingly, the expected standing stocks of shrimp of Bangladesh from the year 1981-82 to 1997-98 have been estimated and presented in Table 3.1.

Table 3.1

Estimated Stock of Shrimp in Different Years.

Year	Estimated Stock . (in metric tons)
1981-1982	4592.004
1982-1983	4545.818
1983-1984	5784.25
1984-1985	6921.284
1985-1986	6406.522
19864987	6629.594
1987-1988	5476.848
1988-1989	7210.16
1989-1990	5783.105
1990-1991	7802.254
1991-1992	4851.165
1992-1993	6066.475
1993-1994	4967.783
1994-1995	3657.025
1995-1996	4966.094
1996-1997	5091.759
1997-1998	3338.899

Source: Estimated by the author.

3.2.2. Carrying Capacity:

In the literature of fishery most widely applied growth model, known as Verhaulst equation, is a logistic growth function given as follows:

$$\frac{\quad}{dt} = F(x) = r\,x\,\left(1 - \frac{-}{K}\right) \qquad (3.4)$$

Where r, assumed to be positive constant, known as intrinsic growth rate. The other positive constant K signifies the saturation level of a particular species in the inhabitant zone and is normally referred to as the environmental carrying capacity.

The solution of the[1] equation (Clark, 1990) indicates that in between two equilibrium solution at x =0 and at x=K, 0 < x < K implies that x > 0 and x > K implies that x< 0. Mathematically, the solution of this logistic differential equation (3.4) is

$$x(t) = \frac{TC}{l + c.e^{"rt}}, \quad \text{where } C = \frac{K - x}{x_o} \text{ and at } t = 0,\ x_0 = x(0)$$

Thus the environmental carrying capacity K is globally asymptotically stable for positive x in the sense that

$$\lim_{t \to \infty} x(t) = K, \qquad \text{provided that } x(0) > 0$$

It actually shows that x(t) converges towards K at an exponential rate as f tends to infinity. Physical interpretation of the solution is that given the reasonable time, biomass stock, either from below the level of K (curve a) or from above (curve b), will approach the saturation level K, as shown in Figure 3.1.

K

• > **t**

Figure 3.1: Typical solution curve of the equation (3.4)

However, the stable equilibrium level must be reduced than the saturation level, once the harvesting is started. It is well known in the literature that, depending on the effort level, stock may be around semi-stable equilibrium *KJ2* or may be reduced to complete depletion. On the basis of this general • phenomenon of fisheries, we make an assumption of estimation of the carrying capacity or saturation level of shrimp stock in Bay of Bengal marine zone exclusively under trawl harvesting of Bangladesh.

Table 3.2
Different Estimation of Shrimp-Stock Made by Different Researchers.

Year of Estimation	Estimated Standing Stock (in metric tons)	Reference
1973	11;400	West, 1973
1983	2,000-4,000	Rashid, 1983
1983	4,000 -6,000	Penn, 1983
1985	3,000 -3,600	White and Khan, 1985
1986	1,550	VanZalinge, 1986

In order to estimate the biomass level of shrimp, regular annual survey had not been done in this area, but occasionally survey method were employed by national and international agencies (like BOBP or FAO, UN). Such occasional estimations made by different researchers at different point of time are shown in Table 3.2.

West (1973) estimated 11,400 metric tons of the standing stock of shrimp on the basis of survey data collected during 1968-1971. The trawl shrimp fishing of Bangladesh commenced from 1972-1973. After the commencement of trawl fishing, Penn (1983), Rashid

(1983), White and Khan (1985), and Van Zalinge (1986) estimated the shrimp stocks. Table 3.2 shows that estimated stock differs significantly from each other. Estimation gives as low as 1550 metric tons to maximum 11,400 metric tons. However, all estimations are much less than the estimation made by West. One of the important and plausible factors of the lower estimation may be the time of survey. While all estimations were made after the year 1973, West completed his survey a few years before 1973. Report, however, was published in December, 1973 by the FAO, UN. Commercial exploitation of trawl shrimp fishery having begun in 1973, the estimations made by others should reasonably be less than that of one made by West. As there was no harvesting before 1973, it could be assumed that the biomass level of shrimp fish was allowed to grow towards saturation level (carrying capacity) in the fishing zone of Bangladesh before 1973. Since the period of survey being (data were collected by West during 1968-71, as we have already mentioned) much earlier than the year in which harvesting was started, West's estimation may be assumed to be an estimation of saturation level of the said fishing zone. As we do not have any other estimation of biomass level prior to the commencement of trawl shrimp fishing, we are assuming the estimation of biomass level of West as carrying capacity. This particular zone of fishing being within the jurisdiction of Bangladesh fishing exclusively, we hope our assumption is not much unreliable barring the limitation of usual survey method. Thus the value of K is set at 11,400 metric tons.

3.2.3. The Intrinsic Growth Rate:

One important parameter in the growth function given in equation (3.4) is V i.e. intrinsic growth rate. This implies net growth of biomass and is obtained by subtracting overall mortality rate from biological population growth rate. Overall mortality rate is sum total of three mortality rates - natural mortality, predator mortality and fishing mortality. We know that the biological population growth rate of a species depends on temperature, salinity and other environmental factors. This value of biological population growth rate, therefore, can be obtained through biological research. Thus intrinsic growth rate can be obtained in two ways. First, by obtaining the biological population growth rate, natural mortality rate, fishing mortality rate and predator mortality rate of penaeid shrimp in this specific zone of Bay of Bengal, we can obtain 'r' by subtracting overall mortality rate from the first factor. Second method could be a Statistical estimation. If we have time series data of biomass level over a period of time and the value of positive constant K, then we can obtain the intrinsic growth rate (r) by estimating the equation (3.4). The test of significance of 'r' can also be done for statistical inference. Problem of applying the first method is that the biological population growth rate of commercially exploited shrimp fish in Bangladesh is not available. Three most important agencies relevant for this specific information - namely, DOF, BOBP and FAO (UN) confirmed us that the estimation has not yet been done in the specific climatic condition of Bangladesh trawl shrimp fishing zone. Thus given the constant carrying capacity K as shown in Section 3.2.2 and biomass level [x (t)] for the time period 1981-82 to 1997-98 as in Table 3.1, we then estimate the intrinsic growth rate (r) by applying OLS method.

Table 3.3

Estimated Value of the Parameter: **Intrinsic Growth Rate (r)**

Parameter	Estimated value	Standard Error	df	t-statistic	Function
r	1.330818	0.136198	16	9.771237	Logistic growth function

Source: Estimated by the author.

The estimated value of Y and other estimated statistics are given in Table 3.3. The value of t-statistic implies that the value of 'r' is statistically significant at 1% level of significance. Thus the value of intrinsic growth rate (r) of Bangladesh trawl shrimp may approximately be considered as equal to 1.330818.

Having the estimated values of the saturation level or carrying capacity (K) in 3.2.2, the intrinsic growth rate (r) in 3.2.3 and biomass stock (x_t) in 3.2.1, we now plot the growth function shown by the equation (3.4), This growth curve is shown by Figure 3.2.

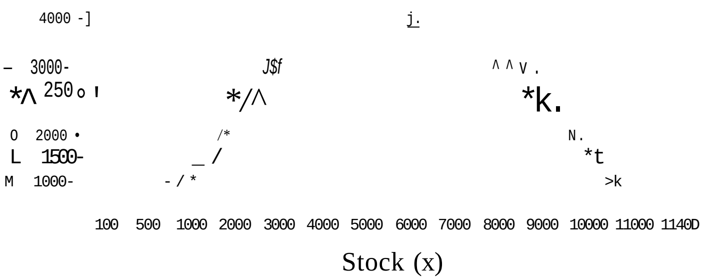

Figure 3.2: Growth Curve for Bangladesh Trawl Shrimp Fishery

3.3. Estimation of Economic Parameters:

As the fishery is considered as an economic resource, therefore, it is assumed that the fishery should be managed to maximize the discounted net revenue overtime. Following this existing practice in fishery, we also assume that Bangladesh trawl shrimp should be managed *in order to achieve the same objective of* optimizing present value of net benefit in terms of revenue. Net revenue is calculated as total revenue less total operating costs. Total revenue is given by the product of harvest and price of fish. The price of the fish is determined by the demand fluctuations expressed by market demand functions. A part of operational cost, on the other hand, depends on the level of effort. But, level of effort to be required in harvesting an unit of catch depends on the biomass stock. The harvest-effort ratio per trawler days is known as catchability co-efficient. For a constant level of effort, this co-efficient will be greater if biomass stock is high and wilt be tow if biomass stock is less. Therefore, the following economic factors are involved with the activities of fishery and are generally incorporated in an optimizing model: (a) parameters of demand function (b) parameters of cost function (c) discount factor (d) catchability co-efficient.

Among these components, first three are economic and the rest, being dependent both on biological factor (biomass level) and economic factor (cost), is considered as bioeconomic.

3.3,1. Demand Parameters:

Three types of demand function have been used in the literatures of fisheries models for different species of fishes by various researchers. Kolberg (1992,1993) and Rowse (1995) used a downward sloping demand function for Northern Anchovy Fishery of California, Grafton *et al.* (2000) used a non-linear demand function for Canada's Northern Cod Fishery. Sandal and Steinshamn (2001) used a non-linear exponential demand function for North-East Atlantic Cod Fishery. As demand function for the market of Bangladesh trawl shrimp fishery has not been estimated by any researcher so far, we have to estimate demand function on the basis of the price and harvest data available for the period 1981-82 to 1997-98. We would try to estimate.all three above mentioned demand functions in order to identify one that gives statistically relatively significant result. Shrimp prices during this period are shown in Table 3.4 and harvests are shown in Table 3.8.

Table 3.4
Shrimp Price in Different Years

Year	Price (per ton iri$)
1981-1982 •	,6531.22
1982-1983	6839.99
1983-1984	7185.98
1984-1985	6083.98
1985-1986	6656.81
1986-1987	6909.8
1987-1988	7772.82
1988-1989	7828.16
1989-1990	7246.84
1990-1991	7115.37
1991-1992 .	,7155.35
1992-1993	8087.7
1993-1994	8963.14
1994-1995	9921.3
1995-1996	10723.92
1996-1997	10846.75
1997-1998	13977.94

Source: Export Promotion Bureau, 2000

(A) Linear Demand Function:

We assume that Bangladesh trawl shrimp fishery follows the linear demand function. Thus the function could be of the following type:

$$p\,(h) = d, + d_2 .\ h \qquad ' \qquad (3.5)$$

where di (the demand intercept) and da (the slope of the function) are the parameters to be estimated here.

We estimate the demand function by using price and harvest data through ordinary least square (OLS) method and get estimated $d_1 = 10,759.389$ and $d_2 = -0.69602$. The OLS results are shown in Table 3.5. The fitted demand curve is shown in Figure 3,2 and observed as well as predicted prices over the period of our study are shown in Figure 3.3.

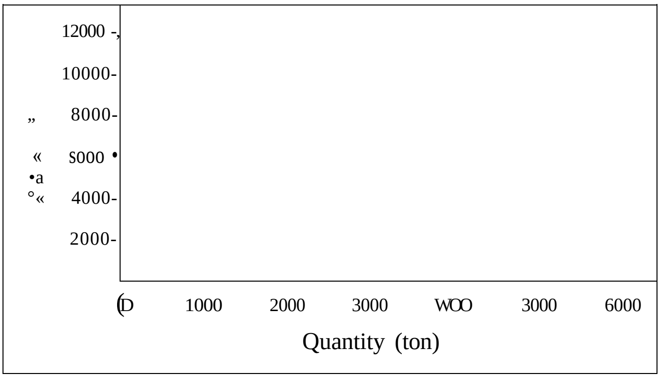

Figure 3.2: Fitted Linear Demand Curve

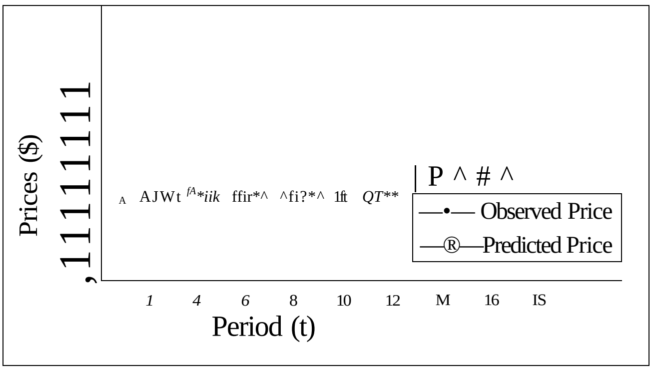

Figure 3.3: Observed and Predicted Prices: Linear Demand Function

(B) Non-linear Inverse Demand Function:

We assume that Bangladesh trawl shrimp fishery follows the-non-linear inverse demand function. Thus the function could be of the following type:

$$p(h) = \frac{p_1 a + p_2 h}{a + h} \qquad (3\text{-}6)$$

where p_1 is the specified minimum price, p_2 is the specified maximum price and 'a' is a parameter to be estimated. As observed during the period 1981-82 to 1997-98 the minimum price and the maximum price are set at \$ 6,083.97729 and \$13,977.93881 per ton respectively. Using the time series data on price and minimum and maximum prices, the parameter 'a' has been estimated using the non-linear regression programme. The simple programme is written in C-language, following the algorithm of true non-linear regression technique that minimizes squared residuals for the specified non-linear function. The estimated value of the parameter 'a' is 850.261.

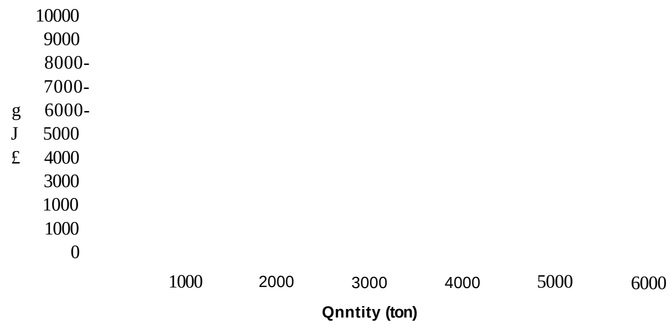

Figure 3.4: Fitted Non-linear Inverse Demand Curve

Other necessary statistical information for inference is given in Table 3.5. The fitted demand curve is shown in Figure 3.4 and observed as well as predicted prices over the period of our study are shown in Figure 3.5.

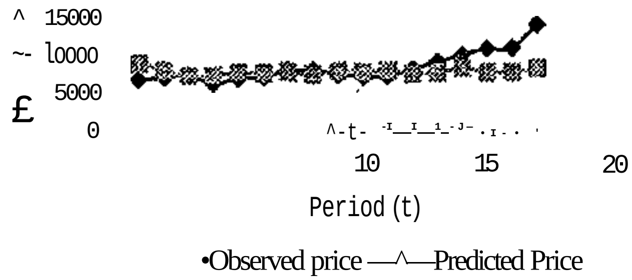

Figure 3.5: Observed and Predicted Prices: Inverse Demand Function

(C) Non-linear Exponential Demand Function:

If we assume that Bangladesh trawl shrimp fishery follows the non-linear exponential demand function, then the function coufd be of the following type:

$$p(h) = p_1 - f - (p_2 - p_l).e^{-bh} \qquad (3.7)$$

The parameters p_1 and p_2 in the demand function represent minimum price and maximum price respectively, as we have already specified in case of inverse demand function. Using the time series on price data and minimum and maximum prices, the parameter 'b' has been estimated using the same non-linear regression programme with a change in place of specified function. The estimated value of the parameter is 0. 0004682. Other necessary statistical information for inference is shown in Table-3.5. The fitted demand curve is shown in Figure 3.6 and observed as well as predicted prices over the period of our study are shown in Figure 3.7.

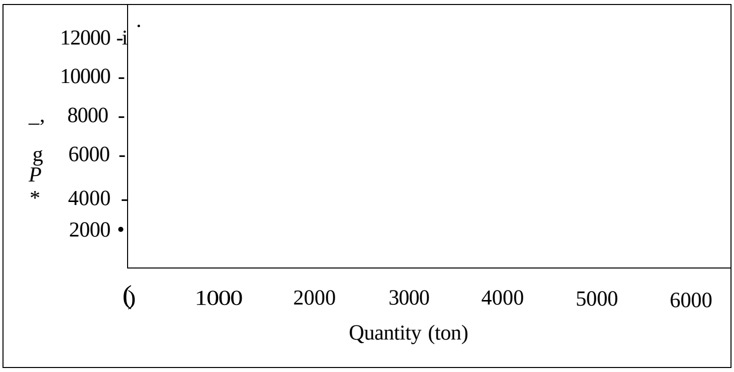

Figure 3.6: Fitted Nonlinear Exponential Demand Curve

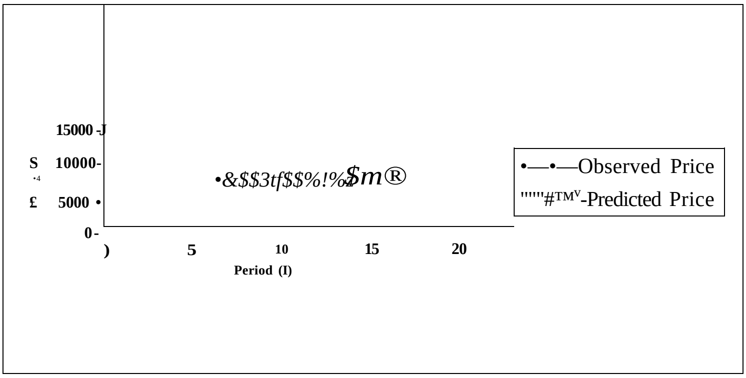

Figure 3.7: Observed and Predicted Prices: Exponential Demand Function

Statistical Comparison Of Demand Functions:

Estimated values of demand parameters of three different types of demand function of Bangladesh trawl shrimp fishery are given in the following table-3.5.

Table 3.5
Estimated Values of Demand Parameters of Three Different Types of Demand Function of Bangladesh Trawl Shrimp.

Function	Parameter	Estimated Value	. » *	Standard Error	df	t-statistic
Linear	di d*	10759.389 -0.69602	0.1242	0.90477 0.477	15	11891.90755 1.45859
Inverse	a	850.261	0.1342	506.33619	16	1.67924
Exponential	b	0.0004682	0.2293	1.003	16	0.00046685

Results indicate that the exponential demand function is relatively 'good fit' for Bangladesh marine shrimp (R^2 = 0,2293) in comparison with other two. in different international recent publications of similar work on fishery management, most often reported values of R^2 are around 0.20. One such example is estimation of demand function made by Grafton *et at* (2000). They used the inverse demand function for Canada's Northern Cod Fishery. The value of R^a of the estimated demand function has been reported as 0.198. One of the possible explanations of the low value of R^2 may be that the price of the shrimp is exogenousiy determined. Marine shrimp production of Bangladesh being insignificant with respect to global as well as national production, the fluctuation in marine shrimp catch in Bangladesh possibly has little impact on price.

However, t-statistic and S. E. of the demand parameters of each of the three functions, except di in linear function, do not appear significant. Since di appears significant but not d_2, it indicates actually that price remains fixed. Another important point is that the difference between values of R^2 of linear and inverse demand function is only 0.01 and between inverse and exponential is only 0.09. It is indicative that three different types of demand function statistically do not differ with each other and the use of any one of three demand functions likely to produce identical results.

However, we obtain the following statistical test of significance*. Denoting the square root of 'co-efficient of determination' for i=1,2,3 for linear, inverse and exponential demand function respectively, we have null hypothesis H_0: P i= Pj, i £ j, which is to be tested against alternative hypothesis Hi: P # P|. Transforming Z i = $^1/_2$In[(1+ri)/(1- nj] for i=1,2,3 an approximate pair wise test for Ho is provided by the statistic

Z.-Z.

yn.-3 + n.-3

which is approximately a normal deviate under.H_0. Computed values are given below:

T-values

	n	r_2	r_3
h	~		
r_2	-0.04	--	
r_3	-0.4056	-0.3633	—

Since, neither of the values exceeds Tooos = 2.576 or TO02S = ,1.960, the null hypothesis is accepted for all pairs of test. It implies that statistically neither of the functions differs significantly with each other.

For this reason, we will use only one demand function for optimal control problem and we prefer exponential demand function which is relatively 'good fit' as well as consistent with demand theory.

3.3.2. Cost Function:

In all the fisheries models, fishing costs have been assumed to be directly related to fishing effort. Fixed costs are assumed to be consisting of (i) registration cost (ii) Ifcense cost

* Rao, C.R.(1974). Linear Statistical Inference and' Its Application (2nd Edn), Wiley Eastern Pvt. Ltd., New Delhi, pp. 432-434

and (iii) cost due to interest and depreciation on invested capital. Those items of costs that are directly proportional to fishing effort constitute the variable cost. The variable cost, therefore, consists of fuel cost, food cost, labour cost (salary of crews), vessel's maintenance cost etc. Costs per unit effort are normally independent of the harvest rate but dependent on the stock level. We assume this very common phenomenon to be true for Bangladesh trawl shrimp fishery. This assumption reflects both long-run factor adjustment opportunities and stock effects on cost along an optimal time path toward a steady state.

A cost function satisfying this set of assumptions, stated above can be derived directly from a production function model of harvest. The well-known Schaefer model assumes that harvest is proportional to fishing effort. Fishing effort is a standard day of fishing for a representative sized vessel in the fleet. Some authors have argued that there could be diminishing returns to fishing time as the gear would become saturated and difficult to work and searchable areas might become larger requiring more search time. The relation proposed by Gulland (1977) and applied by Reed ,(1979) was

$$h = q.\ E.\ x^{u}, \quad \text{with} U = 1 + y$$

$$\text{or, } E .= h / qx^{u} \qquad (3.8)$$

where rf= harvest level, x = biomass level,

q = catchability co-efficient, E = effort level

In the Schaefer model, as y is set equals to zero, the value of U becomes one. In the case of Bangladesh Trawl Shrimp Fishery, Penn (1982/1983) estimated 5,180 square kilometer as the effective shrimp fishing area. The shrimp fishing area is not too large in comparison with the total capacity of the fleet of trawlers generally operate in Bangladesh. This area is easily searchable and may be covered by the existing fleet of trawlers. We thus set U = 1".

$$\text{Therefore, effort is, } E = h / qx \qquad (3.9)$$

The aggregate cost function for fishingeffort is assumed linear; reflecting long-run constant minimum average cost per unit effort allocated and takes the form:

$$C(E) = 02.\ E \qquad (3.10)$$

wh ere c_2 is th e constant proport ion.

From (3.9) and (3.10), we finally get the cost function as,

$$C(h,x) = c_2.\ h/qx \qquad (3.11)$$

where c_2 may be regarded as the slope of the cost function.

The cost function represents an average cost per unit of effort weighted by the ratio of the exploited biomass in the respective year to the current level of biomass. We represent the relevant data for the estimation of cost function from the sample survey in Table 3.6. Using the aggregate survey data for that year an average operating cost per unit of effort was determined. Average annual effort of a shrimp trawler in Bangladesh has been estimated as 200 fishing days (Khan and Hoque, 2000). Total variable cost is thus divided by

* Author acknowledges Professor William C. Kolberg for his suggestion to use U = 1 in reply to our query regarding some problems related to trawl shrimp fishery modelling in Bangladesh.

Table 3.6
Cost Structure

Item	Taka
Fuel Cost	50,61,600
Food Cost	5,43,470
Labour Cost/ Salary of crews	15,38,200
Maintenance Cost	9,42,010
Other Variable Cost	30,19,600
Total Variable Cost	1,11,04,880
Depreciation Cost	14,11,400
Interest Payments	31,46,200
Registration and License Cost	98,770
Total Fixed Cost	46,56,370
Total Cost	1,57,61,250

Source: Khan and Hoque (2000), Sample survey 1998.

the annual effort to obtain cost co-efficient (c_2). For standardizing this value we converted it to dollar value by using the exchange rate prevalent at the time of survey (1 US $ = 48 Taka). Thus, the minimum average cost of effort with representative shrimp trawler was estimated as $1156.76 per effort. This implies that $c_2 = 1156.76$.

3.3.3. Estimation of the Catchability Co-effident:

Catchability co-efficient (q), by definition, is measured by catch per vessel per unit of fishing days. From the time series data of annual average harvest and effort, the catchability co-efficient can be calculated. In Bangladesh, two types of trawlers are employed for shrimp fishing - one is shrimp trawler and the other one is fish trawler. Shrimp trawlers are exclusively engaged in shrimp harvesting. But, the fish trawlers are used for harvesting marine fishes and thus they trawl not only in the shrimp zone but also beyond that. It necessitates adjusting the total effort of shrimp fishing. It is reported that one-third effort of a fish trawler is normally accounted for shrimp trawling (Khan and Hoque, 2000a). We adjust the number of trawlers accordingly. Required number of trawlers is the sum of the number of shrimp trawlers and one-third of fish trawlers (Because of this calculated number of shrimp trawlers may not be integer). However, the adjustment in efforts by the shrimp trawlers and fish trawlers has been made by and provided separately in Khan and Latif (1995). These adjusted values of efforts and number of both types of trawlers are given in Table 3.7.

Unfortunately, separate data of both types of operational trawlers are only available for the period 1981-82 to 1990-91. For this reason, we use the data for the period 1981-82 to 1997-98 in all cases of parameter estimations but catchability co-efficient when we consider the period from 1981-82 to 1990-91. Dividing the catch-effort ratio by adjusted number of trawlers and number of fishing days per trawler in each year, we obtain the catchability co-efficient per vessel for each year of the period. The average of these values gives us the catchability co-efficient (q) for Bangladesh trawl shrimp fishing. The computation of this value is shown in Table 3.7.

Table 3.7
Estimation of Catchabiiity Co-efficient (q)

Year	Total Harvest	Total Effort	Catch/Effort	Total Trawler	No. Of fishing Days	Catchabiiity Co-efficient
1981-1982	1697	3782	0.44870	16.46	200	0.0001363015
1982-1983	3120	7024	0.44419	28.03	200	0.0000792350
1983-1984	5461	9662	0.56520	30.16	200	0.0000937009
1984-1985	5518	8159	0.67631	37.76	200	0.0000895535
1985-1986	4034	6444	0.62601	33.62	200	0.0000931006
1986-1987	4488	6928	0.64781	33.30	200	0.0000972682
1987-1988	3523	6583	0.53517	34.82	200	0.0000768475
1988-1989	4893	6945	0.70454	36.75	200	0,0000958552
1989-1990	3134	5546	0.56509	36.57	200	0,0000772617
1990-1991	3430	4499	0.76239	36.50	200	0,0001044372
Computed Value of **Catchabiiity Co-efficient (q)**						0.0000943561

Source: Calculated by the author on the basis of DOF and BOBP data.

Computing the predicted values of harvest:

We can thus obtain predicted levels of harvest (h') for different years on the basis of calculated value of catchabiiity co-efficient (q) (Section 3.3.3), estimated stock (x) (Section 3.2.1) and standardized effort (E) from Schaefer's equation (3.9). Actual (h) and predicted values of harvest levels (h.) are presented in Table 3.8.

Table 3.8
Actual And Predicted Harvest Level

Year	Total Effort	Stock (Estimated)	Harvest (Predicted)	Harvest (Actual)
1981-1982	3782	4592	1681.14	1697
1982-1983	7024	4545	3090.29	3120
1983-1984	9662	5784	5409.73	5461
1984-1985	8159	6921	5466.21	5518
1985-1986	6444	6406	3995.97	4034
1986-1987	6928	6629	4445.66	4488
1987-1988	6583	5476	3489.54	3523
1988-1989	6945	7210	4847.17	4893
1989-1990	5546	5783	3104.66	3134
1990-1991	4499	7802	3397.83	3430
1991-1992	6122	4851	2874.78	2902
1992-1993	7065	*6066*	4148.54	4188
1993-1994	7169	4967	3446.93	3480
1994-1995	6761	3657	2393.40	2416
1995-1996	7394	4966	3554.40	3588
1996-1997	7107	5091	3502.43	3536
1997-1998	7491	3338	2420.51	2444

Source: Calculated by the author on the basis of DOF and BOBP data.

Table 3.8 shows that the predicted harvest levels (h) by using the estimated value of q are very close to the actual harvest levels (h). This seems to imply that our estimated stock levels of biomass (x) may reasonably be presumed to be dependable for further use in studying the optimizing aspects of this resource under commercial exploitation.

However, a frequency distribution of the difference between h and h may be obtained by simulating the values of q in equation (3.9) if the values of effort (E) and biomass (x) are assumed to be given and remained constant. We can thus obtain the refined value of q for which this difference is minimum. We find that this value of q = 0.0000977332. We will use this value of q in our subsequent work.

3.4 Concluding Remarks:

The assessment of standing stock of any commercially exploited renewable resource like shrimp is of great importance for the effective control of exploitation. Earlier stock estimates are so widely varied that it is not possible to reach any conclusion. Moreover, estimations at different point of time do not give the time series data of biomass level. But the present day management decision making process for optimal control on resource's utilization and exploitation, demands time series data. We have generated time series data of shrimp stock of Bangladesh by Pauly's model using trawler and swept area specific values. Interestingly, most of the values are lying between the lower and upper limit of the estimation made by Penn (1983). Moreover, considering the present level of harvest in each year and the MSY calculated by the earlier workers, these values seem to be good fits. The estimations made by White & Khan (1985), Van Zalinge (1986) and Rashid (1983) appear to be conservative, because if their estimates are valid, the present levels of harvest could not be sustained at the current rate of intrinsic growth (r).

Apart from the estimation of biomass stock of shrimp in Bay of Bengal of Bangladesh, we have estimated some biological and economic parameters in this chapter. These are (a) carrying capacity (b) intrinsic growth rate (c) demand parameters and (d) cost parameters.
Demand parameters show statistically insignificant results. Estimation of demand, however, seems to indicate that there is no significant difference between linear, inverse and exponential demand function. Moreover, low value of R^2 possibly suggests that the price is exogenously determined. However, we prefer to consider exponential function in order to formulate non-linear dynamic models in next chapters as it relatively 'good fit' and consistent with demand theory.

Values of the parameters estimated in this chapter are to be used in discrete and continuous time non-linear dynamic optimization models for the Bangladesh trawl shrimp in the subsequent chapters of this thesis.