A Model to Determine Benefits Obtainable from the Management of Riverine Fisheries of Bangladesh

Mahfuzuddin Ahmed

ICLARM
INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT
MANILA, PHILIPPINES

in Ag. '93

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Printed in Manila, Philippines

Published by the International Center for Living Aquatic Resources Management, MC P.O. Box 1501, Makati, Metro Manila, Philippines through the financial assistance of the Ford Foundation, Dhaka; and Winrock International Institute for Agricultural Development, c/o the Bangladesh Agricultural Research Council, Farm Gate, Dhaka, Bangladesh.

Ahmed, M. 1991. A model to determine benefits obtainable from the management of riverine fisheries of Bangladesh. ICLARM Tech. Rep. 28, 133 p.

ISSN 0115-5547
ISBN 971-8709-08-8

Cover: Small-scale fishing using liftnet in a small river adjoining the Jamuna River near Dhaka, during the flood season, Bangladesh. Photo by M. Ahmed.

ICLARM Contribution No. 728.

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CHAPTER 1

INTRODUCTION

The pervasive tendency of open-access fisheries to expand effort to the point where resource rent is dissipated, first pointed out by Gordon (1954) and then by many others after him, has been a major cause of concern within the sector all over the world. In many fisheries, the tendency to overexploit the resources has driven stocks to levels below their (maximum yield) potential and has worsened economic conditions of the fishing communities depending on these resources.

The fisheries of Bangladesh contribute 71% of the animal protein supply of the country. Nearly one-tenth (10 million) of the country's population is involved as part-time and full-time workers in fishing and related activities. The inland fisheries employ nearly one million full-time fishers (BBS 1986; World Bank 1991).

The conditions of the inland capture fisheries of Bangladesh have deteriorated in recent years and production has either stagnated or even decreased for some major species (DOF/BFRSS 1985, 1986, 1991). On the other hand, the fishing-dependent population has been on the increase, signifying a mounting pressure on the available fisheries resources (BBS 1989 and previous issues). The traditional system of administering fisheries activities is insufficient to maintain production from the various fisheries and, more importantly, to the task of maintaining the flow of benefits that the fisheries are capable of generating.

In Bangladesh, most of the inland fisheries exploitation activities are small-scale and traditional. Over the years, these fisheries have retained an open-access character in the absence of a consistent and effective management policy. For a long time the fisheries had been managed by a group of middlemen who secured yearly leases from the government through auctions. Consequently, an increasingly large fishing dependent population and an excess fishing effort relative to the availability of stock have contributed to declining catches of some or all species and a deteriorating fishing income. These fisheries will require some kind of control of effort in order to improve their economic performance.

In response to these problems, a comprehensive policy for inland fisheries management is in the process of implementation by the government. The objective of this New Fisheries Management Policy (NFMP) is mainly to redirect the potential benefits of fisheries exploitation activities to "actual fishers" and at the same time maintaining and improving the productivity of the fisheries on a sustainable basis. In this effort, a system of licensing of water bodies to actual fishers or groups of fishers has been introduced in selected areas of inland fisheries. This would replace the traditional system of leasing out the water bodies to private individuals. The economic consequences of these new practices are yet to be addressed (Agüero et al. 1989).

A major problem confronting management policies is the determination of the type and level of control which should be applied to the fisheries in order to achieve best the above objectives. This necessitates the understanding of the performance-response of the fisheries to alternative management policies in terms of the resultant impact on the beneficiaries or users of the resources, i.e., the fishers, the trading community and the consumers.

The principal objective of this research was to develop a bioeconomic model that would provide a basis for assessment of economic consequences of various alternative management measures for the inland fisheries of Bangladesh.

Resources Externalities and Economic Inefficiency in Open-Access Fisheries

In an open-access fishery, benefits tend to be dissipated because whenever a positive benefit occurs (as in a newly developing fishery or with an increase in the price for the product), additional factor inputs of labor and capital are attracted. This tends to continue until revenue per unit of fishing effort is equated to the level of its marginal opportunity cost (Scott 1955; Copes 1972; Munro and Chee 1978; Christy 1982). The exploitation of fishery resources under open-access conditions, as such, will result in a suboptimal allocation of resources as far as strict economic efficiency is concerned. This was established in the seminal work on fisheries economics by Gordon (1954), by introducing economic variables into the logistic model of population growth in fisheries of Schaefer (1954).

Uncontrolled access to fishing stocks induces fishers to compete among themselves for available fish resources. As a result, there is little incentive for individual fishers to restrict their fishing effort in the general interest of maintaining fish stocks since any fish that an individual fisher leaves in the water may be captured by another fisher. This situation results in dissipation of the economic rent that resources can generate, through overcapitalization and overfishing. As such, we find the industry characterized by production costs that are excessive relative to the value of production. Fishers, therefore, eventually find themselves in an untenable position with considerable investment in vessels and equipment that cannot be instantly liquidated (Cauvin 1979). In small-scale fisheries of developing countries, investments are not as great as in large-scale fisheries, but the results are the same as there are few employment opportunities consistent with their skills and experience.

Second, as a result of excessive fishing effort, and despite harvest control measures, fisheries resources are subject to overexploitation (Scott 1979). Finally, the potential economic value of the resource to society in the form of a resource rent becomes dissipated (Cauvin 1979). This is a classic case of the "Tragedy of the Commons" (Hardin 1968).

Various forms of externalities result from open competition in the harvesting sector of the fishery. They include: (i) crowding externalities due to vessel congestion on fishing grounds; (ii) misallocation of effort among species and fishing grounds; and (iii) distortion in the use of factors of production, e.g., incentive to adopt new technologies faster than is socially desirable (Greboval 1985).

Management Alternatives

The literature on fisheries economics divides fisheries regulations into two broad categories: conservation measures to protect and enhance stock productivity and management measures aimed at economic efficiency.

Conservation measures such as closed season or area and control of mesh size have received considerable attention by fisheries regulatory authorities. For instance, following the conceptualization of eumetric fishing by Beverton and Holt (1957), the control of mesh size became a very popular regulatory instrument. The consequence of eumetric fishing is to increase the yield and biomass; the latter being important if

FOREWORD

The present document is based on a thesis in resource economics presented at the Faculty of Economics and Management, Universiti Pertanian Malaysia, Kuala Lumpur, in July 1989.

In the course of his thesis work, Dr. M. Ahmed spent, besides the obligatory field work in Bangladesh, his homeland, a period of almost three years at ICLARM Headquarters in Manila from 1986 to 1988, both to learn from and contribute to various projects related to his work, and conducted by other ICLARM staff, notably Dr. M. Agüero and Ms. A. Cruz-Trinidad.

It is now with considerable pleasure that I introduce this document - our first Technical Report devoted to Bangladesh - to its readers. It illustrates - if need be - that economists have much to contribute to fisheries research and management. Indeed, such a comprehensive view of the freshwater fisheries of Bangladesh as presented in this document has never been elaborated by the biologists - local and expatriate - who have studied the inland fisheries of Bangladesh: the biologists have tended to concentrate on details of the biology of the resources species and to forget the "big picture".

This big picture, as presented to us by Dr. Ahmed, is that the fisheries in question are extremely valuable and could generate, under the optimal conditions he identifies, a net surplus of nearly 1.4 billion Taka, i.e., over US$40 million per year. He also identifies and quantifies the main constraint to the realization of this surplus: excess fishing effort, the plague of the world of fishing.

Finally, he presents a cogent case for the implementation of the New Management Policy promulgated by the Government of Bangladesh, as well as providing guidelines for further studies.

I can only hope that this document will find, among decisionmakers and scientists alike in Bangladesh and elsewhere, an attentive readership. Comprehensive studies such as that presented here are few and far between.

Dr. DANIEL PAULY
Director
Capture Fisheries Management Program
International Center for Living Aquatic Resources Management

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ABSTRACT

An operational model was derived which can be used to analyze the performance of Bangladesh riverine fisheries under different simulated alternatives of technical, economic and biological conditions.

Functions and parameters of a Base Model were estimated by deriving two submodels: (a) bioeconomic production and (b) the market, using regression techniques. Both primary and secondary data were used for empirical estimation of the submodels.

The model was developed in a linear programming framework to represent various fisheries in the riverine waters of Bangladesh. Results of the Base Model suggest that the riverine fisheries of Bangladesh are capable, under optimal conditions, of generating a total net benefit of BDT (Bangladesh Taka) 1,383 million per annum (US$1 = BDT32), of which 96% would accrue as producer surplus. Also, a significant overcapacity (118%) exists in the existing fleet in terms of application of effort relative to the resource availability.

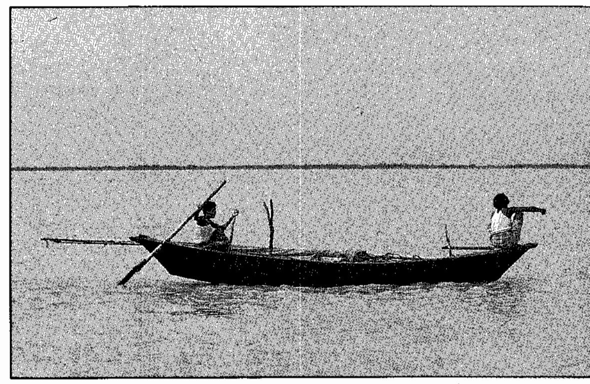
Simulation of cost and demand changes reveal that the effect of changes in the cost condition of harvest will in general be related negatively to the intensity of total effort use, total landings, benefits and costs while the effects of changes in the aggregate demand on total effort, total costs, landings, prices and net benefits will be positive. The implication of the results for management is that intervention into the fisheries through control on effort intensity would produce substantial net benefits from the fisheries.

Hilsa, the major riverine species in Bangladesh.

Aspects of the Riverine Fisheries in Bangladesh

(Photos by M. Ahmed)

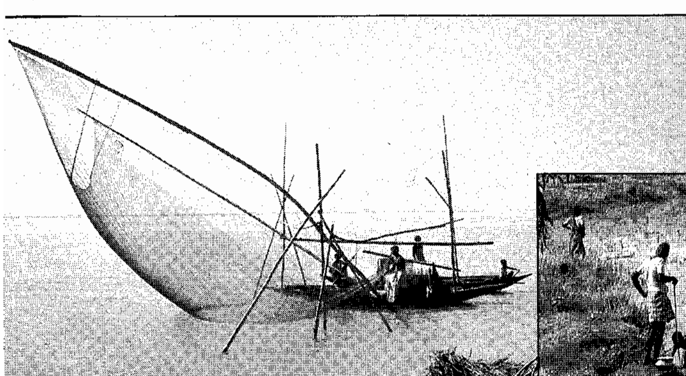
Fishing operation using seine net in Buringonga river near Dhaka, Bangladesh.



Hook and line fishing in Jamuna River, near Aricha, Bangladesh.

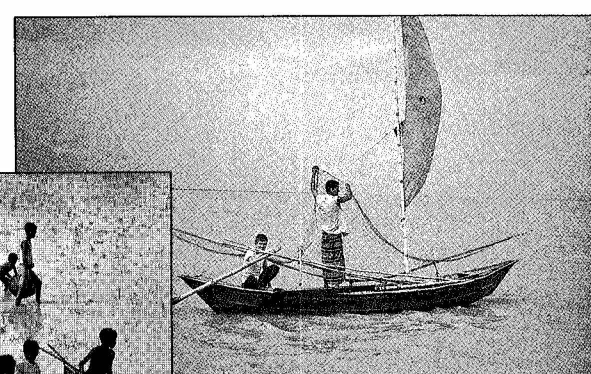
Local fish market in Manikgonj near Dhaka, Bangladesh.

Fish landing site along a river in northeastern Bangladesh.



Small-scale fishing using liftnet in Jamuna River, Bangladesh.

Intensive fishing operations in floodlands near Mymensingh, Bangladesh.



Small-scale fishing using liftnet in northeastern Bangladesh.

recruitment is stock dependent. However, in an open-access fishery, the rent created by eumetric fishing will only induce additional entry and the basic problem of economic inefficiency will persist (Turvey 1964). Therefore, these traditional forms of control may help protect stocks from destructive forms of effort, but are ineffective in regulating the amount of effort. In fact, severe overcapitalization occurred in some world fisheries as a consequence of measures such as catch quotas or closed seasons or areas (Crutchfield 1965; Greboval 1985). In addition, these measures (catch quota, season and area closure) affect the processing and marketing sector of the fishery by inducing peak and slack processing times, increased inventories and freezing, and price distortions (Anderson 1977). Thus, economists have tended to rely on management measures that reduce total inputs (effort) for any given catch level and encourage least-cost combination of inputs. Such measures include taxes, limited entry and quotas.

Theoretically, with an appropriate tax, fisheries could be left to the market without fear of biological depletion, of excessive inputs in general, or of the incorrect combination of inputs (Crutchfield 1979). Either inputs (effort) or output (landings) may be taxed. However, in order to produce its fullest effect, taxes must be factor-neutral (Crutchfield 1979). In this respect, a tax on landings makes a better impact. In addition, McConnell and Norton (1978) suggest that differential landing taxes in a mixed-species fishery could improve economic output significantly by making use of the fishers' self-interest and their limited ability to alter the species mix in their catch.

Finally, taxes serve as means of offsetting any adverse effects on the distribution of wealth, income or employment; taxes could be used to convert the social costs of management to an explicit charge on the productive activity of the participants.

There are, however, at least two practical difficulties with using taxes. First, they are politically infeasible in most parts of the world. Second, if taxes were used they would have to be dynamic, changing frequently, causing enormous administrative difficulties (Moloney and Pearse 1979).

Entry restriction reduces fishing inputs directly, by restricting fishing to holders of a legal right of access - a license, permit, or other legal evidence that a particular vessel and crew may use the resource. However, entry restrictions must be in terms of a limit upon one or more of the measures used in the industry. This is because rationing the supply of any resource used in the industry through entry restrictions will invite substitution of other resources for it (Turvey 1964).

Experiences with limited entry programs in many fisheries across the world have proven to be ineffective because some of the unregulated dimension of the fishing effort expanded to such an extent that substantial overcapitalization (capital stuffing) had occurred and much of the potential rents were eventually dissipated (Fraser 1979; Meany 1979; Pearse and Wilen 1979; Copes and Cook 1982).

There are exceptions. Newton (1978) acknowledged the growth of excess capital under limited entry in British Columbia fisheries with qualifications. Also, Meany (1979) citing the cases of rock lobster and shrimp fisheries of Australia under limited entry programs showed that there has been less tendency of overcapitalization and, hence, little dissipation of resource rent in shrimp fisheries compared to lobster fisheries.

In tropical multispecies fisheries, limited entry programs by license limitations and vessel and gear restrictions have been used to restrict catch level and to change catch compositions in order to prevent overexploitation (Beddington and Rettig 1983; Majid 1984). Although the success of such measures have not been fully assessed, Yahaya (1988) in discussing the issues and constraints of fishery management and regulation in Peninsular Malaysia, pointed out that license limitation may also lead to operating inefficiency among licensed vessels through increase of unregulated dimension of effort.

The third alternative in regulating exploitation intensity would be to create rights to specific quantities of fish (individual quotas) rather than simple rights to participate in the fishery through vessel or personal license. Under an individual quota system there is no incentive to overinvest in the vessel and gear. This would avoid some of the regulatory problems encountered in limited entry licensing, the dilemma between restricting technology to check capital stuffing through socially inefficient increase in fishing capacity and allowing free play to promote socially efficient cost reducing techniques.

The quota holders will select the least cost combination and deployment of inputs, including technological improvement and innovation without subjecting the resource to a surge of new fishing mortality (Crutchfield 1979). In addition, harvest glut can be avoided or reduced and a higher value of sales achieved by optimally meeting the time patterns of demand over the year (Copes 1986).

Despite the superiority of quotas, especially over limited entry licensing (see Christy 1973; Moloney and Pearse 1979; Scott and Neher 1981), in practical management terms, deliberate application of individual quotas are not seen free of defects. Copes (1986) gave an exhaustive list of areas where individual quotas face problems of implementation. Most of them are relevant for tropical fisheries where the operations are small scale with numerous actual and potential marketing channels and geographically widely dispersed activities.

In the case of inland fisheries of Bangladesh, thousands of small boats land their catches at hundreds of places and sell directly to the public at numerous local markets. Monitoring and enforcing any kind of limits on inputs and outputs would appear impossible. However, a limited entry program through licensing may still conform to ease of implementation and flexibility compared to taxes and quotas. The fear of capital stuffing through overinvestment in unregulated dimension of effort would be minimal, since the fisheries are mainly traditional and nonmechanized.

Analysis of Existing Economic Models of Fisheries

Fisheries are complex systems, consisting not only of the stocks of fish species and their surrounding environment, but also including the mechanisms of harvesting, processing, transporting and marketing activities, as well as the social and institutional setup under which the economic organization of the fishing industry takes place (Charles 1988). A multidimensional approach has to be adopted for capturing the essence of its various aspects, e.g., production, population dynamics, marketing and property systems.

Certain types of models, each used separately, could not suitably deal with the problem at hand. Each of them could only represent a part or subsystem, e.g., production, fish population, marketing and management, of the entire fishery process.

Several approaches to analyzing the implications of various management schemes are available. Mathematical models of the fishery which include biological and some economic factors have been found to be useful tools for determining the best regulatory scheme. Some familiar examples of these models are given by Schaefer (1954, 1968), Beverton and Holt (1957), Ricker (1958), Larkin (1963, 1966), Pella and Tomlinson (1969) and Fox (1970).

However, the above models dealt mostly with biological parameters and describe how fisheries (often a single-species fishery) change with time under a steady-state situation, whereas, in most cases fisheries operate under complex biotechnological and socioeconomic conditions. The inclusion of these factors in the analysis results in multivariable models which are complex.

Much of the previous analysis of fisheries is based on the concept of an equilibrium, e.g., the maximum equilibrium yield analysis. Such an equilibrium is an idealization and is never encountered in reality because of the continually changing environment which acts as a disturbance and thereby displaces the system from its equilibrium conditions (Palm 1975). Moreover, the steady-state models may lose their applicability in complex fisheries when the time dimension is considered.

Unlike biological fishery management models, most of the fisheries economics models dealing with management problems were cast largely in static terms, based on a theory of fisheries management founded by Gordon (Clark and Munro 1975). Scott (1955) viewed fish population and biomass as a capital stock, capable of yielding a sustainable consumption flow through time, and thus attempted to cast the problem of management of a fishery resource as a problem in capital theory. This was followed by Crutchfield and Zellner's (1962) formulation in terms of a dynamic mathematical problem.

Optimization techniques, to maximize or minimize a particular function, may involve either linear or quadratic programming. Zellner (1961), Rothschild and Balsiger (1971), Mueller et al. (1979) and Agüero (1987) applied linear programming to the economics of fisheries management. Mueller and Vidaeus (1981) developed a quadratic programming model for an optimal fishery strategy. The problem can be set either in a static or a dynamic frame. A simple dynamic approach was used by Rothschild (1971), who optimized the route of a fishing vessel. Quirk and Smith (1970) applied a time dynamic programming model to economic optimization of a fishing industry. Booth (1972) developed a discrete time-profit maximizing model. More recently, Wang and Mueller (1981) developed a model that deals with intertemporal issues and economic analysis in fisheries management. Palm (1975) showed the use of a static optimization method in conjunction with a dynamic method as a total approach. In this method, maximization is first done with static methods and then a feedback control function is constructed to keep the system near the resulting equilibrium condition.

In selecting models, several considerations have to be made. For instance, if the multispecies fishery characteristics call for an interactive approach, analytical models are more appropriate than single-species production models based on catch and effort data derived for a multispecies fishery (Greboval 1985). Another consideration is the data requirement of analysis. For example, in multiple strategy fishing, the catchability coefficient (fraction of stock removed by a unit of effort) can be better estimated using cluster analysis. However, the need for intensive data renders the use of such methods impracticable (Greboval 1985).

Technologocial interaction and mixed harvest strategy would yield an optimal harvest rate for the aggregate of stocks different from the theoretical maximum of each individual stock. However, if economic yield is maximized by equating marginal cost of fishing effort to the marginal revenues of a mixed catch, an optimal mix of production is achieved. Proper bioeconomic management of multispecies fisheries, therefore, requires control of overall amount of effort and some degree of control over the mix of production. An interactive method can be applied to achieve such objectives. Optimization techniques have been used for economic optimization of mixed stocks by several authors, e.g., Quirk and Smith (1970), Anderson (1975), Meuriot (1981), Agüero (1983) and Logan (1984).

Conclusion

The situation in Bangladesh warrants developing or devising methods that will take proper account of the problem of poor quality data and the complex interaction of various factors, e.g., technological interaction and mixed species harvest. It is important that the fishery process be represented by a model that is flexible and powerful enough to accommodate data and information gaps. A mathematical programming approach is considered appropriate and suitable because:

(i) it can handle a large number of variables of complex interdependence;

(ii) the objective function (e.g., maximization of consumer plus producer surplus) can measure the achievement of management objectives; and

(iii) the model is capable of identifying an optimal strategy for allocation of effort in a mixed-species harvest with geographical and seasonal variability in the species distribution.

CHAPTER 2

INLAND FISHERIES OF BANGLADESH

Bangladesh is a huge delta of 144,000 km² formed by three main rivers: the Padma (Ganges), Meghna and Jamuna-Brahmaputra and their tributaries (Fig. 2.1). The size of the riverine (flowing river and estuaries) and other large inland perennial water bodies has been estimated to be about 12,200 km², i.e., over 8% of the area of Bangladesh (Table 33 in Appendix A). The major fisheries take place in: (a) rivers and estuaries, (b) *beels* (natural depressions) and *baors* (dead rivers), (c) floodlands (seasonal floodplains) and (d) an artificial lake (Kaptai Lake).

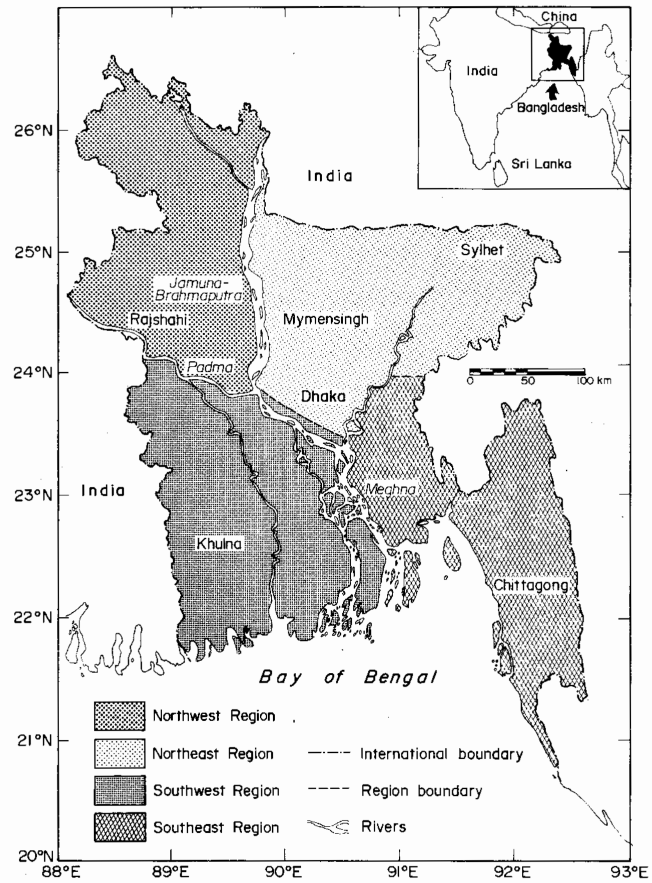


Fig. 2.1. Map of Bangladesh: river systems and geographic regions.

The Production System

The inland capture fisheries are tightly bound to the pattern of the floodings which take place during the monsoon season. The yearly inundation of the countryside connects all the aquatic areas into one production system for up to four months (July-October). It is during this season that a major expansion in both numbers and biomass of fish takes place. Some of the major carps (*Cyprinidae*) and various floodland-dependent species spawn then and the fry spread all over the flooded area during this period. The ability of the fisheries to sustain themselves depends on extensive systems of interconnected areas of aquatic habitat that provide for reproduction and growth.

Estimates of the annual fish production from various water environments and area under each environment are shown in Table 2.1; a total of 424,140 t of fish were produced in 1988-89 from four million hectares of inland open-water area. Moreover, the area of land intermittently inundated during the monsoon season to a depth of 30 cm or more (sufficient to support fish production) is estimated to be about 5.5 million ha (MPO/HARZA 1985b). Hilsa (*Hilsa ilisha*), carps (e.g., rohu *Labeo rohita*, catla *Catla catla*, mrigal *Cirrhinus mrigala* and kalbasu *Labeo calbasu*) and a few floodland-dependent species like catfish (e.g., "boal" *Wallago attu*, "pangas" *Pangasius pangasius*, "air" *Mystus aor*) and different types of prawns (*Macrobrachium* spp.) are the important species in the inland open waters. The

Table 2.1. Areas of different types of fisheries and annual production in Bangladesh, 1988-89. (Source: DOF, unpubl. data)

Subsector of fisheries	Area ($ha \cdot 10^3$)	Production ($t \cdot 10^3$)	%	Yield ($kg \cdot ha^{-1}$)
Inland fisheries				
Open water/capture				
Rivers and estuaries	1,031.60	181.14	22	176
Sunderban		6.42		
Beels	114.16	47.02	6	412
Lake Kaptai	68.80	3.44	0	50
Floodlands (seasonal)	2,832.79	186.13	22	66
Subtotal	4,047.35	424.14	50	105
Closed water				
Baors	5.49	1.32	0	241
Ponds	146.89	155.01	18	1,055
Coastal aquaculture	108.28	27.17	3	251
Subtotal	216.63	183.51	22	847
Total inland	4,307.97	607.65	72	141
Marine fisheries				
Industrial (trawl)	-	10.35	1	-
Artisanal	-	222.93	27	-
Total marine	-	233.28	28	-
Grand total	-	840.93	100	-

major harvest periods of some economically important fish of Bangladesh are presented in Fig. 2.2. In general, except for hilsa, harvests from rivers take place in the postmonsoon period. The peak harvest of hilsa is during the spawning migration in the late monsoon period (August-October). A list of important fish is contained in Appendix C.

The annual or seasonal beels, which either dry up or are dried intentionally, are completely harvested each year during postmonsoon months. The permanent beel is a shelter fishery, and under the current management system, harvest is recommended only every third year to allow the fish populations to recover.

Harvest of the floodlands fish is done mainly for subsistence throughout the monsoon months (June through September). The peak harvest generally occurs during periods of receding or rising water when fish are trapped while coming to or going from the floodlands. The annual fish harvest from the floodlands through subsistence fishing has been estimated at 186,130 t in 1988–89 (Table 2.1), and as many as 10.8 million (73%) households were involved in these fishing activities in 1987-88 (World Bank 1991).

On the other hand, riverine fisheries are important for small-scale commercial fishing year-round. The total area of river environments scattered all over the country is 10,316 km^2 producing about 181,140 t of fish annually (Table 2.1). Table 2.2 shows the production figures for different species in the riverine waters (rivers and estuaries). Hilsa is the dominant species, amounting to about 44% of the average annual riverine fish production (Table 2.2).

Major Inland Fisheries

HILSA FISHERY

The hilsa, an anadromous fish (i.e., migrating from the sea into rivers to spawn), is found in the foreshore areas, estuaries, brackishwater lakes and freshwater rivers of

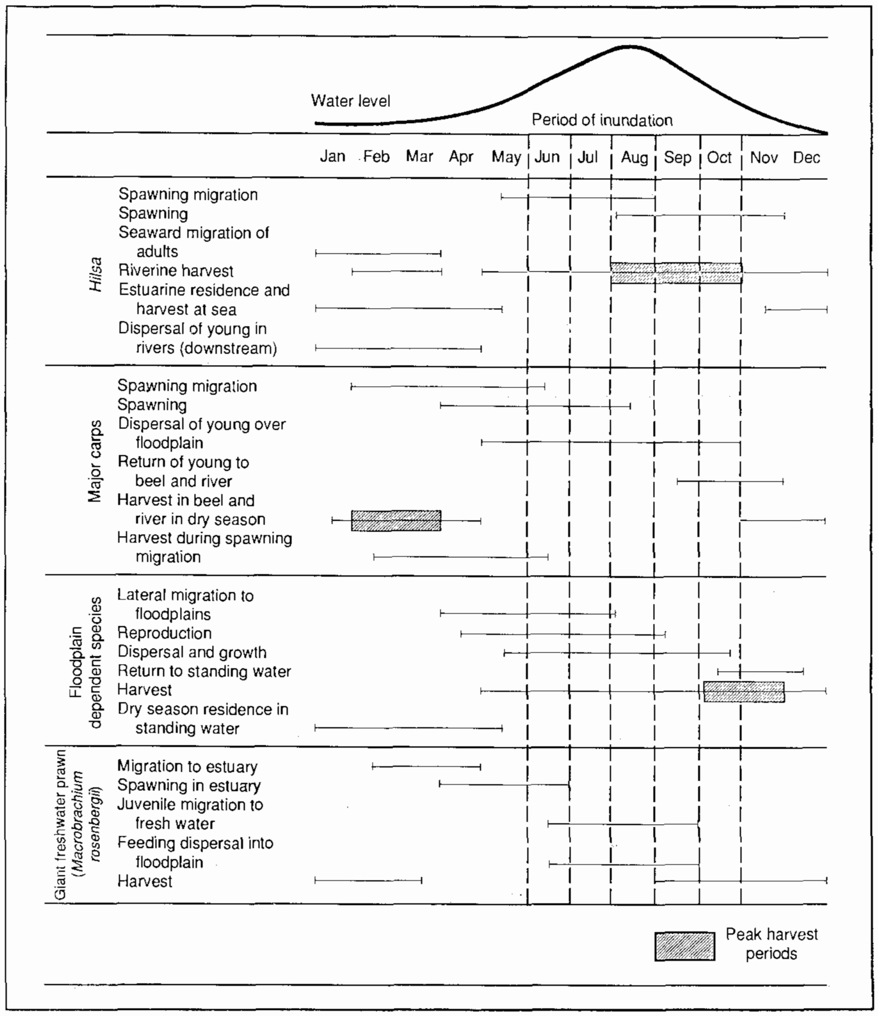


Fig. 2.2. Seasonal changes in the biology and fisheries of fish and prawns in the open waters of Bangladesh (Source: MPO/HARZA 1985a).

South and West Asia. The largest yields of hilsa fishery come from the deltaic region of the Gangetic system of India and Bangladesh. Of the three countries in the upper Bay of Bengal region (India, Bangladesh and Burma), where hilsa forms a commercial fishery, Bangladesh secures the largest share (more than 80%) of the landings, about 150,000 t·year^{-1} from its inland river systems and inshore waters (Raja 1985; Islam 1989). In Bangladesh, the share of riverine production is at present less than 50% of the national production of hilsa (World Bank 1991).

No scientific assessment has been made so far on the population distribution of the various stocks of hilsa in the rivers, estuaries and inshore marine waters of Bangladesh (Dunn 1982). However, the dominant age and size in the population distribution is believed to be 1+ to 2+ years and 25-40 cm, respectively (Raja 1985). Normally, hilsa attains maturity at the age of 1+ year when it has reached a size of 25-30 cm. Two principal breeding runs have been reported in Bangladesh, one during the southwest monsoon (June-October) and the other during winter (November-March). The latter is of smaller magnitude (Raja 1985).

The fishing season of riverine and estuarine stocks extends from June to March, with a major peak in September-October and a minor one in February-March. In 1988-89, over 81,000 t of hilsa were harvested from various inland rivers and estuaries, 68% of which came from the principal river, Meghna (Table 2.2). The fishery belongs to the artisanal sector using mainly gill/driftnets and operates with the help of traditional

Table 2.2. Recent annual catches (t) of various species from the rivers of Bangladesh. (Source: DOF/BFRSS 1985, 1986; DOF, unpubl. data).

Species	Meghna River	Padma River	Jamuna River	Other Rivers	Total
Hilsa					
83-84	55,302	4,193	533	30,054	90,082
84-85	35,133	5,253	670	32,272	73,328
85-86	66,947	1,815	541	24,830	94,133
86-87	62,356	2,643	979	24,570	90,548
87-88	49,152	2,207	605	25,613	77,577
88-89	55,367	968	507	24,265	81,107
Average	54,043	2,847	639	26,934	84,463
Prawn					
83-84	3,075	348	468	9,965	13,856
84-85	3,957	358	575	15,682	20,572
85-86	2,274	73	343	26,269	28,959
86-87	3,106	238	198	20,117	23,659
87-88	1,390	376	196	16,841	18,803
88-89	2,149	200	148	17,025	19,522
Average	2,659	266	321	17,650	20,895
Catfish					
83-84	1,539	869	1,012	6,559	9,979
84-85	2,603	1,041	898	7,992	12,534
85-86	1,113	268	1,096	4,122	6,599
86-87	239	413	573	2,518	3,743
87-88	440	122	642	2,148	3,352
88-89	370	82	576	1,961	2,989
Average	1,051	466	800	4,217	6,533
Carp					
83-84	1,142	174	924	8,387	10,627
84-85	810	184	563	10,626	12,183
85-86	541	137	573	3,489	4,740
86-87	100	106	303	1,511	2,020
87-88	86	35	414	1,676	2,211
88-89	630	8	543	4,208	5,389
Average	552	107	553	4,983	6,195
Miscellaneous fish					
83-84	9,741	4,904	7,477	61,000	83,122
84-85	10,384	5,259	8,597	70,200	94,440
85-86	14,489	1,600	6,025	40,491	62,605
86-87	15,988	1,897	2,616	36,646	57,147
87-88	17,417	464	1,742	62,251	81,874
88-89	11,330	1,149	1,401	58,253	72,133
Average	13,225	2,546	4,643	54,807	75,220
All species					
83-84	70,799	10,488	10,414	115,965	207,666
84-85	52,887	12,095	11,303	136,772	213,057
85-86	85,364	3,893	8,578	99,201	197,036
86-87	81,789	5,297	4,669	85,362	177,117
87-88	68,485	3,204	3,599	108,529	183,817
88-89	69,846	2,407	3,175	105,712	181,140
Average	71,528	6,231	6,956	108,590	193,306

nonmechanized plank built, undecked or partly decked boats. Melvin (1984) reported that a large expansion in effort has taken place in this fishery over the years and a large increase in effort has provided only marginal increase in landings in recent times.

CARP FISHERY

The carp fishery is important in the principal rivers Padma, Jamuna and Brahmaputra and the beels and basins of Faridpur, Rajshahi and Sylhet-Mymensingh. The populations of major carps in various parts of the Padma-Meghna-Brahmaputra river system come from three main stocks: the Brahmaputra stock, Padma stock and Meghna stock (Tsai and Ali 1985). In their early life (up to 3+ years of age), the carps prefer to reside in the *beels*, basins and floodlands. After they become sexually mature at the age of 3+ years, they become permanent riverine residents. During their first three years of life, they disperse amongst the inundated basins in the flooding season and resettle randomly in *beels*, rivers and *baors* as the water level subsides during the dry season (Tsai and Ali 1985). The spawning migration of carps toward (upstream) rivers occurs in February-June. Spawning continues until August. Young carps disperse over the floodlands during the monsoon months (June-October). From September until November, when the water level starts subsiding in the dry season, the young carps return to the *beels* and rivers. Harvest of carps in *beels* and rivers takes place mostly in dry season (January-April); the peak fishery occurs between February and March. Carps are also harvested during the spawning migration between February and June.

Studies on carp populations have shown that the population structure differs in different *beels* and river habitats, particularly across different geographical locations. These differences could be due to the differences in the origin of the stock and the size, depth and physical structure of the various river and *beel* habitats. However, the important factors that cause significant differences in the population structure, particularly age structure, are the effectiveness of gear used and the intensity of fishing. For instance, intensive use of *katta* (fish aggregating device) fishing in beels in Faridpur and drift gillnet (*fasi jal* and *pait jal*) fishing in the Padma River might have caused a decline of the stock of young carp over one year old in these areas. At present about 6,200 t of various carp species are harvested annually from rivers (Table 2.2). The size of the carp harvest from other environments (e.g., *beels*, floodlands and *baors*) is more than 10,000 t (World Bank 1991). In pond culture, carp is considered one of the preferred species, which is supported by a fry gathering industry in the rivers (Tsai and Ali 1985).

A wide variety of gear is used for carp fishing. In the riverine fishery, *katta* fishing and *jal* (net) fishing are important. *Katta* fishing operates in the secondary rivers and associated canals. Drift gillnet, fixed gillnet, dragnet and castnet are extensively used for carp fishing in the rivers. In "beel" fisheries, small *beels* are harvested through dewatering. For large seasonal *beels* and permanent *beels*, *katta*, castnet, dragnet and mosquito netting seine are the important gears (Tsai and Ali 1985).

GIANT FRESHWATER PRAWN

The rivers Padma and Meghna are important sources of giant freshwater prawns (*Macrobrachium* spp.). The adult prawns migrate toward estuarine waters for spawning during February-April. Spawning in estuarine water takes place between April and June. The juvenile prawns migrate toward freshwater during the monsoon rains (June-September) and disperse into the floodlands for feeding and growth. Harvest of freshwater prawns in the rivers takes place from September until March (when adult prawns migrate toward estuaries for spawning) (Goodwin and Hanson 1974). A variety of gear is used to harvest prawns. Important are the dragnet, seine, fixed pursenet, stakenet, dipnet and castnet.

In terms of total landings, freshwater prawns constitute the second largest fishery after hilsa in the rivers. Total average landings of prawns from the rivers are 20,895 t·year^{-1}(Table 2.2). However, a declining trend in the proportion of large individuals in the total catch of freshwater prawns from the rivers has been observed in recent times (DOF, unpubl. data).

FLOODLAND-DEPENDENT SPECIES

A number of fish are captured from the open-water fishery. A majority of these species depend on floodlands for their spawning and early life. Lateral migration of these species toward the floodlands takes place during April-August and reproduction occurs between May and September. Throughout the flooding season they disperse into the floodlands and grow fast. As soon as the monsoon waters start receding, these fishes return to the small rivers and/or to *beels* and reside there during the whole dry season. Harvesting takes place from May until December, with a peak occurring between October and December. The gears used for harvesting these species are numerous as they are spread in different types of open-water environments. Appendix C contains a list of the most important among these species.

Some of the catfishes (e.g., *pangas*, *boal* and *air*) constitute a major fishery in the rivers. The total catch of catfish in 1984-85 was 6% (12,500 t) of the total riverine harvest. However, the species have been showing a declining trend.

Finally, a feature that characterizes the fisheries in the rivers are the geographical and seasonal variability of species composition in the total harvest. Table 2.3 shows the percentage composition of annual landings from the rivers in the three geographic regions. As an example, nearly 90% of the hilsa and 60% of the total riverine landings come from the Lower Meghna and other smaller rivers in the southwest region (Region

Table 2.3. Percentage share of annual landings of different species from rivers in different regions of Bangladesh (1983-87). (Source: DOF, unpubl. data).

Region	Hilsa	Carp	Catfish	Prawn	Misc.	Total
Region A	9	74	42	62	55	34
Region B	89	8	36	36	31	59
Region C	2	18	22	2	14	7
Total	100	100	100	100	100	100

Region A: Southeast and northeast region (Upper Meghna river and other rivers in the region); Region B: Southwest region (Lower Meghna, Lower Padma and rivers in the region); Region C: Northwest region (Upper Padma, Jamuna-Brahmaputra and other rivers in the region).

B) of Bangladesh. Table 2.4 shows the composition of annual landings by season (wet and dry). It shows that 73% of hilsa and 60% of total catch are landed during the wet season. This feature is reflective of varying species abundance among different fishing grounds and seasons. This is also evident from Fig. 2.3, which shows the distribution of catch by species and by river.

Production Organization and Dynamics of Fleet Operations

Activities in inland open-water fisheries can be divided into three major parts: harvesting, postharvesting handling (processing, transporting, storing and marketing) and retail selling. Of these, harvesting is the most critical, involving the interaction of biotechnology and economic factors.

Table 2.4. Seasonal share (%) of landings of different species from rivers in each region of Bangladesh, 1983-87. (Source: DOF, unpubl. data).

Items	Hilsa	Carp	Catfish	Prawn	Misc.	Total
Region A						
Dry season	13	54	64	29	4	38
Wet season	87	46	36	71	57	62
Total	100	100	100	100	100	100
Region B						
Dry season	28	66	49	59	49	35
Wet season	72	34	51	41	51	65
Total	100	100	100	100	100	100
Region C						
Dry season	28	64	64	41	51	50
Wet season	72	36	36	59	49	50
Total	100	100	100	100	100	100
All Regions						
Dry season	27	59	62	40	49	48
Wet season	73	41	38	60	51	52
Total	100	100	100	100	100	100

Region A: Southeast and northeast region (Upper Meghna river and other rivers in the region); Region B: Southwest region (Lower Meghna, Lower Padma and rivers in the region); Region C: Northwest region (Upper Padma, Jamuna-Brahmaputra and other rivers in the region).

Harvesting activities are organized by traditional fishers from the poor and landless population. The primary level of the harvesting organization is a fishing unit. A unit consists of a group of two to fifteen fishers depending on the size and type of boat and gear.

Fishing in the rivers requires a substantial investment in vessel and gear, which the majority of fishers cannot afford. Generally, a few rich fishers and middlemen traders own these inputs. The other fishers either rent these inputs for fishing purposes or join as a crew member on a catch sharing basis. The distributional mechanism of catch among boat and gear owners and labor fishers varies among fisheries and fishing grounds. In general, 50% of the net revenue (total sales minus operating expenses) is taken by the boat and gear owner(s), called the proprietor or *malik*, and the remaining 50% is shared among the crew members according to their roles and skills (Khaled 1985; Ullah 1985).

The fleet is heterogeneous with respect to boats and gear. Table 2.5 shows the distribution of annual landings of different species of fish by type of gear. As high as 94% of hilsa and 52% of the total landings are caught by gillnet and 42% of the operating units are gillnetters. Statistics on the distribution of gear by species are not available. However, individual fishing units normally direct their efforts toward target species. The catch includes a significant by-catch (i.e., nontarget species). Since the abundance of species varies across seasons, the fleet dynamics also allow individual fishing units to change their target species between seasons.

Demand Relations and Markets

Fish are transported from the fishing grounds to the principal landing centers and wholesale markets through various market intermediaries and middlemen dealers, e.g.,

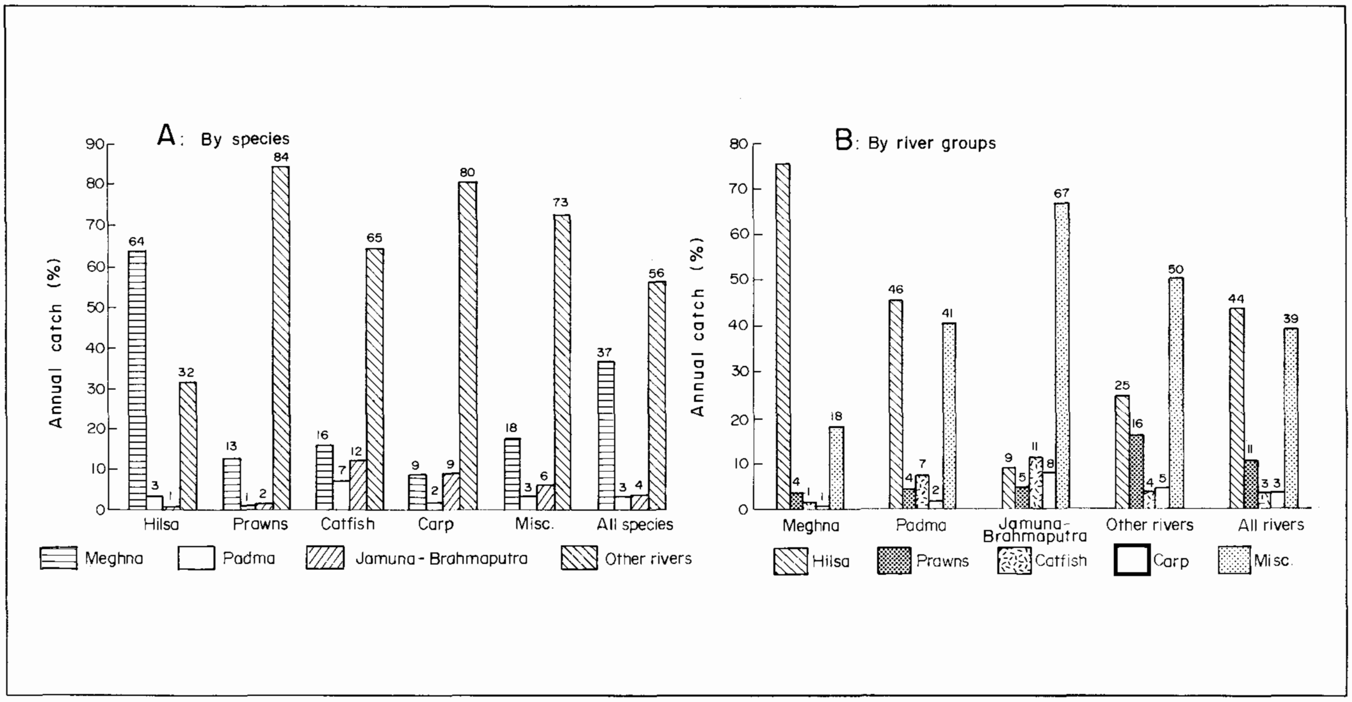


Fig. 2.3. Percentage composition of average yearly catch in the rivers of Bangladesh, 1983-84 to 1988-89.

Table 2.5. Distribution of annual catch (t) from the rivers of Bangladesh by type of gear, 1985-86. (Source: DOF/BFRSS 1985, 1986; DOF, unpubl. data).

Species	Gillnet	Seine	Clapnet	Liftnet	Setnet	Castnet	Other nets	Total
Hilsa	88,177	3,887	1,312	327	263	20	79	94,065
(%)	(94)	(4)	(1)	(0)	(0)	(0)	(0)	(100)
Prawn	475	3,582	128	2,321	21,266	292	899	8,962
(%)	(2)	(12)	(0)	(8)	(73)	(1)	(3)	(100)
Catfish	1,880	1,799	27	198	257	545	1,869	6,576
(%)	(29)	(27)	(0)	(3)	(4)	(28)	(8)	(100)
Carp	1,637	2,282	65	344	29	409	42	4,808
(%)	(34)	(47)	(1)	(7)	(1)	(8)	(1)	(100)
Misc.	11,274	23,869	418	8,902	13,237	2,343	2,581	62,625
(%)	(18)	(38)	(1)	(14)	(21)	(4)	(4)	(100)
Total	103,442	35,419	1,950	12,093	35,053	3,610	5,469	197,036
(%)	(52)	(18)	(1)	(6)	(18)	(2)	(3)	(100)
No. of fishing units	.5,444	1,329	8,619	2,630	5,323	2,184	1,553	37,101
(%)	(42)	(4)	(23)	(7)	(14)	(6)	(4)	(100)

assemblers, commission agents (*aratdars*) and local traders. Fig. 2.4 shows the main marketing channels of fresh fish harvested from open waters of Bangladesh. Transportation takes place by water, rail and road. In urban areas, fish are distributed by headload, push cart and rickshaw (FAO/Rapport 1986).

Generally, fish reach the domestic consumers in the form in which they are captured or harvested, without processing. However, preservation techniques of freezing, icing, salting and drying are used to move products to distant markets.

Except for giant freshwater prawns taken for export, all fish from the inland open waters are consumed locally. Domestic fish prices at the ex-vessel landing centers and wholesale and retail locations are generally determined by the interplay of market

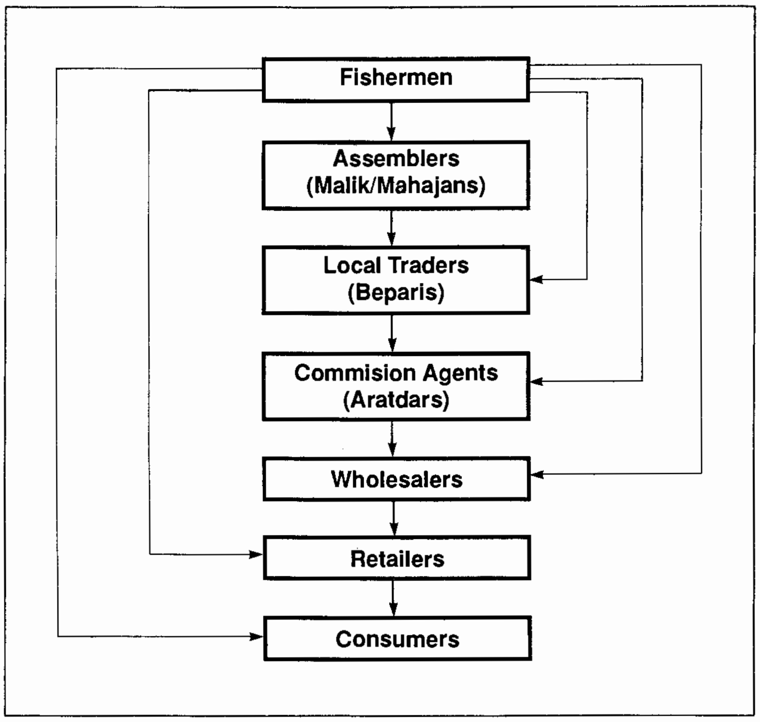


Fig. 2.4. Main marketing channels of fresh fish from the riverine fisheries of Bangladesh.

forces. However, since fishing is still a hunting activity, periods of glut and scarcity alternate. These influence market supply in the short run. In the medium run, seasonality is the influencing factor. Accordingly, the trend is for price to be lower in the dry season (November-February) when *beels* are intensively fished; higher in the early wet season (March-May) when there are less fish in the rivers; and moderate in the later part of the wet season (June-September) when monsoon rain introduces extensive floodlands fisheries (Fig. 2.5).

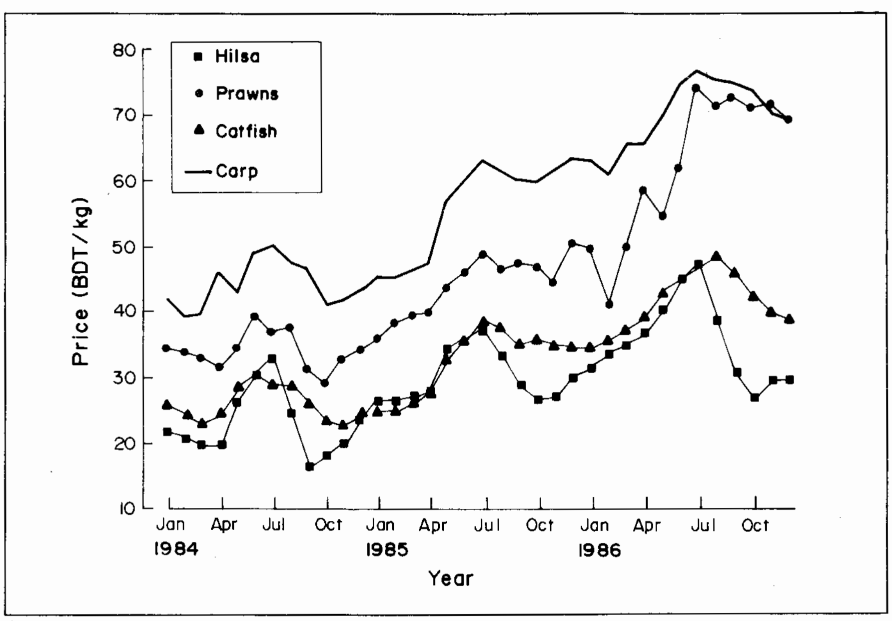


Fig. 2.5. Monthly average retail prices of major riverine species in Bangladesh, showing seasonal trends and overall price increases over time.

Management and Tenure: Their Implications

Following the provisions for settlement of land and waters under British rule (Permanent Settlement of 1793), fisheries in Bangladesh were classified as either "proprietary fishing" or public right of fishing. Proprietary fishing was characterized by an exclusive right to fish (or to allow fishing), whereas the public right of fishing was characterized by open access with common rights of fishing. With the commencement of the East Bengal Estate Acquisition and Tenancy Act of 1951, both common property rights as well as the private property rights in the fisheries of Bangladesh were substantially abridged by the government. The government possesses the rights of exclusion or the right to set the conditions and terms of access to the fishery resource or its services. Other than the privately owned freshwater ponds and some brackishwater areas, all the inland water areas are, in fact, state property, held under the jurisdiction of different government agencies. There are three broad categories of public water bodies and of the fisheries they support, each having a separate system of administration and control: (i) open fisheries; (ii) closed fisheries; and (iii) reservoir fisheries. The management mechanism in the open fisheries and its implications for exploitation pattern and income generating potentials are discussed below.

Open fisheries consist of rivers and canals, *beels*, *baors* and lakes linked to the river system. These are divided into units of variable sizes and shapes, leased out to individuals or groups of individuals (e.g., cooperatives) on an annual basis, except in certain cases where three-year leases are allowed. The leaseholders collect tolls from fishers depending on the type and size of boats used for fishing. The type of toll is also different in different open-water environments. In some areas, the toll is a fixed amount (e.g., in Meghna River) while in other areas (e.g., Jamuna River, Kaptai Lake), it is a percentage of total fish output. In some cases, the proportion of toll ranges up to one-third of the gross catch (Ullah 1985). The leaseholder keeps a big group of employees who help in the collection of tolls as well as in the administration of the leasehold.

In some permanent *beels*, which are considered as closed fisheries, a three-year leasing system is followed. These types of *beel* are concentrated in the Sylhet-Mymensingh basin in the northeast and Faridpur basin in the southwest.

Aside from these, there are small fisheries which are either free (water bodies reserved to support worship of Hindu deities) or held at a fixed rent in perpetuity (which were previously owned by private owners before the East Bengal Estate Acquisition and Tenancy Act 1951 came into effect). The government earns no revenue from these types of fisheries.

In principle, the leasing policy for fishing rights ascribes to sustainable productivity of the fisheries, raising government revenue and spreading the benefits to more disadvantaged segments of the population. Such aims of the government were manifested in its attempt to amend the leasing procedure to include provision of preferences to fishers, strict adherence to fishing regulations and raising the lease-value from time to time.

While fishing regulations (Fish Act 1950) are incorporated in the lease agreement in an effort to sustain productivity, in practice the lessee is seldom constrained by them. In fact, anybody engaged in fishing in a particular leasehold can retain access into the fishery as long as the leaseholder is paid the toll or tax from time to time. Therefore, in the absence of explicit adherence to the minimal regulatory measures, the open-water capture fisheries of Bangladesh retain an unrestricted free-access nature. (The term free-access (Weitzman 1974), open-access (Clark 1976) and free entry (Hartwick 1982) are all used to describe the same phenomenon).

Although access rights are privatized by the highest bidder in the leasing process and thus water bodies become a sole ownership property, theoretically an efficient way to manage the resources (Copes 1972; Clark and Munro 1980), the specific procedures and conditions under which the leasing mechanism operates turn resources eventually to open access. Periodicity of leasing (usually one year) with no assured renewal gives a low degree of security of tenure. As such, the lease holders set a revenue-oriented objective in the management and organization of harvesting activities during the period of lease tenure. Often, this induces lessors to seek the largest possible aggregate fishing toll by encouraging entry of as many possible fishers into the fishery (Agüero and Ahmed 1990). All of these imply that no individual, collectivity, or planner is able to control the rate of exploitation of the fish stocks. Access or entry to the stock is virtually free or open. The stock is exploited (or is exploitable) by all fishers.

It is feared that there has been an enormous decline in the inland fishery (especially hilsa and carp) resulting from overfishing (Raja 1985; Tsai and Ali 1985). As seen from Fig. 2.6, the total inland catch of fish dropped by more than 25% in 1975-76. However, the fishing dependent population has been steadily increasing over time. Indeed, the total catch over the years is more or less stable, except for the sudden drop in 1975-76. One might suspect such a fluctuation could have occurred due to some adjustment in the statistical recording procedure after 1974-75. Another possible reason could be the loss of capital assets, e.g., gear and boat during the famine of 1974, implying a substantial loss of fishing power which could not be replaced in the subsequent years.

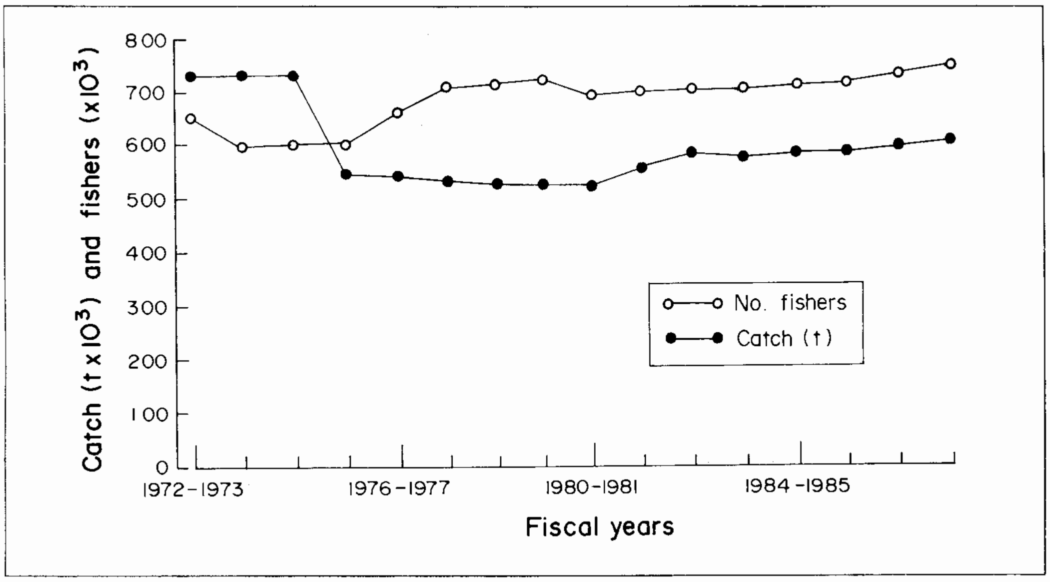


Fig. 2.6. Capture of fish and number of fishers in the riverine fisheries of Bangladesh.

In any case, given the lack of information and a weak and inconsistent database, it is hard to quantify biological overfishing.

Nevertheless, the situation is alarming on economic grounds. The free entry situation in the fisheries continues to cause an increase in the fishing dependent population even though the industry is operating at very low rates of return, due to the low opportunity cost of labor and the high unemployment and population growth rates.

Fundamental Relationships

The economic component in the biological production of a fishery is the fishing effort and its associated cost. This was first pointed out by Gordon (1954). Conversion of cost of effort into cost of output gives the traditional supply relationship in the product market. Copes (1970) incorporated the Schaefer-type sustainable yield curve in the cost of output relations. This is represented in Fig. 3.1.

The long-run yield function (biological production) for a fishery can be exhibited in terms of the sustainable yield curve (SYC) shown in quadrant IV of Fig. 3.1, derivable from Schaefer-type logistic growth of stocks, which is assumed to be a function of its biomass (Schaefer 1954, 1957; Anderson 1977).

The curve in quadrant IV of Fig. 3.1 shows the relationship between catch and effort. It shows that successive units of catch would require a higher amount of effort. In other words, catch per unit of effort decreases with the increase in the level of effort. Moreover, once the maximum sustainable yield level (MSY) is reached, subsequent increase in effort will reduce the total catch that can be obtained on a sustainable basis.

In physical terms, each unit of effort can be said to be composed of a combination of standard size of labor, vessel, gear and other production inputs per unit of time. The market price of these inputs constitutes the cost of effort. Under perfect competition this market price represents the opportunity cost of effort. Since each unit of effort is capable of catching a certain amount of fish, the cost of a particular unit of effort is equivalent to the cost of producing the corresponding amount of fish. If cost per unit of physical inputs (effort) is constant, a decreasing catch per unit of effort as shown by the SYC would imply an increasing cost per unit of catch. This relationship is shown in quadrant I of Fig. 3.1, where the long-run average cost curve for fish harvesting wiil slope upward and bend backward beyond the MSY, shown in quadrant IV.

If there are other costs per unit of fish produced at the processing, storing and transporting stages before it is sold to the consumers in final product form, the average cost curves can be moved up proportionately to include those dimensions of costs. The

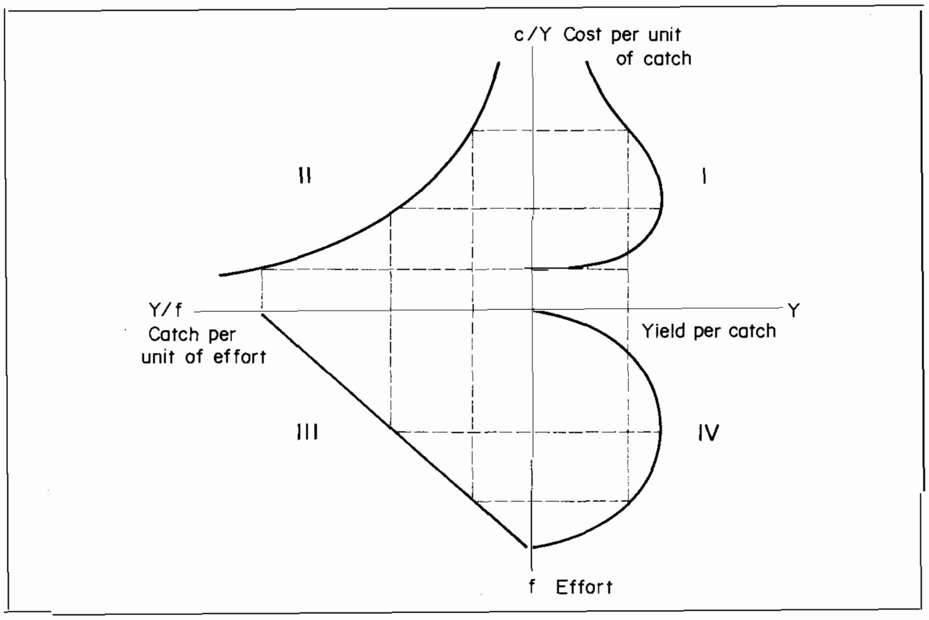


Fig. 3.1. Fundamental relationship between catch, effort and cost in a fishery. Explanation in text.

costs involved at the postharvest levels can be considered as margins in the marketing chain, and under perfect competition they represent the opportunity cost of all the factor inputs used along the marketing chain (Tomek and Robinson 1981).

Product Market Equilibrium in Fishery

The long-run (marginal) cost curves of output consistent with the long-run biological yield function can be used to represent the supply relationships in the market. The market demand function can be super-imposed to determine the optimal strategy for fisheries exploitation. Assumptions on different producer behavior can also be simulated in terms of product market equilibrium (Fig. 3.2). In Fig. 3.2, the line labeled DD is the demand curve for fish, AC is the average cost of output (fish) and MC represents the marginal cost of cutput.

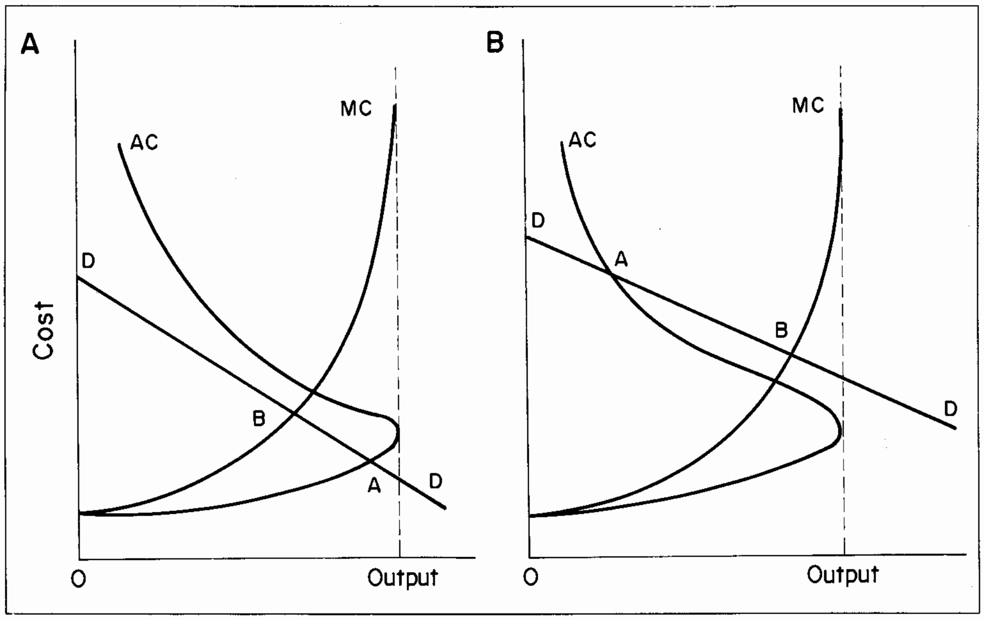


Fig. 3.2. Market equilibrium of fishery sector in a supply-demand model. See text for explanation.

Generally, in an open-access fishery each fisher operates in such a way that the aggregate effort expands to a point where the value of fish caught per unit of effort is equal to the cost of effort. In the output space (Fig. 3.2) such a point is reached where price of fish equals the average cost per unit of fish caught (point A). Under this circumstance net economic surplus (net value of the fishery to society) reduces to only consumer surplus (area under the demand curve above the equilibrium price).

On the other hand, if the fishery is managed with the objective of yielding maximum benefits to society, then the equilibrium would be reached at the point where price equals marginal cost (shown by point B in Fig. 3.2). At this level the net value to society would be the area above the marginal cost curve and below the demand curve, or in other words, the sum of producer and consumer surplus. This net value, however, will include management cost not borne by the industry, such as regulations and enforcement costs paid by the taxpayer. On the other hand, where management actions affect the productivity of vessels, the cost curves would shift, resulting in reductions in consumer and producer surplus. These would be management costs paid by the industry (Mueller and Wang 1981).

Therefore, if the fishery operates at the open-access equilibrium, NSB are always lower whereas cost per unit of fish output is always higher than where economic efficiency is introduced through optimal management (the point where price equals marginal cost). However, the amount of fish harvested can be different. If under open-access equilibrium the amount of effort or production inputs applied are below or equal to that required to harvest MSY, the output will be higher than suggested by or consistent with maximum economic efficiency (the output for which NSB is maximum). This is shown in diagram (a) of Fig. 3.2. Again, when open-access equilibrium is only slightly beyond MSY, the open-access harvest is likely to be larger than the optimal (maximum economic efficiency) harvest. But if open-access harvest is far beyond MSY the opposite is likely to be the case. This is shown in diagram (b) of Fig. 3.2.

In an economy where resources are to be allocated to harvest several independent stocks/species commanding different prices depending upon the species type and product processing, programming formulation can be used to determine the optimal harvesting strategy for each stock/species with an objective function that maximizes net economic benefit to society. The programming model can be used to depict optimal solutions consistent with economic efficiency.

Structure of a Price Endogenous Fisheries Programming Model

Individual Model

An individual fisher or fishing unit is assumed to produce some amount of homogeneous output of fish and compete with others for the same factors of production. Each producer has a finite set of production processes (technology) and alternatives, each representing a particular way of combining various factors to produce one unit of output. The objective of the individual (fisher or fishing unit) would be to maximize profit. Therefore, the production process and/or alternatives that maximize profit is chosen (McCarl and Spreen 1980).

Suppose there are s different methods of harvesting a unit of fish from an environment/fishing ground j composed of i different species. Let C_{sj} be the cost of harvesting a unit of fish from the j^{th} environment/fishing ground using the s^{th} method. Denoting the amount of fish harvest by H_{js}, the total cost of harvesting will be equal to $\Sigma\Sigma C_{js} \cdot H_{js}$.

Assuming g different alternative ways of processing the harvested fish before they are stored and subsequently shipped to the market as final product, denote R_{gij} to be the amount of processed fish of species i obtainable from a total harvest H_{ij} of the j^{th} environment/fishing ground, so that $H_{ij} = \Sigma q_{gij} R_{gij}$ (the variable q being the multiplier between harvested and processed species indicating the amount of harvest required to produce one unit of processed fish). If C^{p}_{gi} denotes the cost per unit of processed fish of species i processed by method g, then the total processing cost for the harvested species will be equal to $\Sigma\Sigma\Sigma C^{p}_{gij} \cdot R_{gij}$.

Assuming differences in the cost of transportation to the market centers for each species processed under each of g different alternative ways and transported by h different alternative methods, the total cost of transportation can be represented by $\Sigma\Sigma\Sigma\Sigma C^{t}_{ghij} \cdot T_{ghij}$, where T is the total amount of processed fish and C^{t} is the cost of transportation per unit of processed fish at the level of transport.

Let Q_{ki} be the amount of final fish product k of species i sold in the market at a price of P_{ki}. Therefore, the total revenue will be $\Sigma\Sigma P_{ki} \cdot Q_{ki}$.

Given the prior assumptions, the producer's profit function can be written as:

$$Z = \Sigma\Sigma P_{ki} \cdot Q_{ki} - \Sigma\Sigma C_{js} H_{js} - \Sigma\Sigma\Sigma C^{p}_{gij} \cdot R_{gij} - \Sigma\Sigma\Sigma\Sigma C^{t}_{ghij} \cdot T_{ghij} \quad ...1)$$

where

$\Sigma\Sigma P_{ki} \cdot Q_{ki}$ = total revenue;
$\Sigma\Sigma C_{js} H_{js}$ = total cost of harvest;
$\Sigma\Sigma\Sigma C^{p}_{gij} \cdot R_{gij}$ = total processing cost; and
$\Sigma\Sigma\Sigma\Sigma C^{t}_{ghij} \cdot T_{ghij}$ = total transport cost.

Now, assume that A_{es} is the use of the e^{th} factor in the s^{th} activity (production process) and A_e is the quantity of e^{th} factor available to the producer.

From the definitions given above the following constraints occur:

- *Resource Constraint*

$$\Sigma A_{es} \cdot H_{js} \leq A \quad ...2)$$

(e = 1, .., p; s = 1, .., S; j = 1, .., J)

- *Balance Equation between Harvesting and Processing*

$$\sum_{s} \alpha_{ijs} \cdot H_{js} - \sum_{g} q_{gij} \cdot R_{gij} = 0 \quad ...3)$$

(g = 1, .., G; i = 1, .., m)

where α_{ijs} = % of species i out of total H_j and, $\Sigma\alpha_i = 1$

- *Balance Equation between Processing and Transport*

$$R_{gij} - \sum_{h} T_{ghij} = 0 \quad (h = 1, ..., r) \quad ...4)$$

- *Balance Equation between Transport and Marketing*

$$\sum_{ghj}\Sigma\Sigma T_{ghij} - \sum_{k} Q_{ki} = 0 \ (k = 1, ..., n) \quad ...5)$$

Thus, the producer's problem may be formulated as the following linear programming problem:

Max (1),

subject to (2) to (5) above, and

$$H_{js}, R_{gij}, T_{ghij}, Q_{ki} \geq 0 \quad ...6)$$

Given the values for all the necessary parameters and prices, the problem can be solved easily via linear programming. The Khun-Tucker conditions provide the necessary and sufficient conditions for a constrained maximum at the equilibrium values of the variables in equation (6).

Aggregate Model

In a perfectly competitive market, the individual producer cannot affect factor or product prices. However, when the number of producers of a certain sector are significant consumers of a factor or suppliers of a product, the interrelationship of prices and quantities needs to be considered in dealing with an aggregate model. Furthermore, since all individual producers in a fishery direct their efforts in competition with the others to harvest a common stock of fish, the decision to invest by an individual depends, among other factors, on the level and intensity of effort being exerted as an aggregate, relative to the availability and abundance of the stock of fish. Such interrelationships are more clearly reflected in aggregate models.

Assume that the inverse demand relation for the final product k of the sector exists as given by equation (7).

$$P_k = f(Q_k, Y), \ (k = 1, 2, \ldots, n) \qquad \ldots 7)$$

where Y is a vector of exogenous factors and Q is a n x 1 vector with elements which equal the total sector's output consumption.

On the other hand, considering the smallness of the fishery sector relative to the agricultural sector as a whole, we assume the supply price of factors to be given even at the aggregate level. Nevertheless, the fact that as effort expands the amount of catch per unit of effort declines will eventually make the average and marginal cost of output (supply function) an increasing function of output (Fig. 3.2).

Therefore, the function relating cost to output is given by

$$C_k = g(Q_k, N), \ (k = 1, 2, \ldots, n) \qquad \ldots 8)$$

where N is a vector of exogenous factors and Q is a n x 1 vector with elements which equal the total sector's output.

The underlying premise for the aggregate model that would incorporate behavior of micro firms can then be stated as follows (McCarl and Spreen 1980):

The production levels of each activity can be determined by the first order conditions with which an individual producer will select a production level. Additionally, demand and supply relations lead to an aggregate model wherein participants individually behave as small competitive units, yet collectively, price and quantities are endogenous. Therefore, the conditions that reflect this premise can be constructed and an optimization model can be developed to yield these conditions. This will require redefining of all variables to include producer dimensions. Let H_l be the level of harvest by the l^{th} producer (l= 1, 2, ..., L). Similarly, let R_l, T_l and Q_l be the levels of processing, transporting and selling activities (in terms of quantity of fish/fish products) performed by the l^{th} individual. Using these definitions, it follows that the sectoral harvest of fish from j^{th} environment/fishing ground and final supply of the k^{th} output are, respectively,

$$H_{lj} = \Sigma H_{lj} \ (j = 1, 2, \ldots, J) \qquad \ldots 9)$$

$$Q_k = \Sigma Q_{lk} \ (k = 1, 2, \ldots, n) \qquad \ldots 10)$$

From the above micro conditions the aggregate conditions can be constructed so that maximization of equation (1) subject to equations (2) to (5) will provide inputs for the aggregate model.

In the aggregate model, however, rather than output price and cost being constant, it may now be given by the functional relations (11) and (12), respectively.

Assuming that both demand and marginal cost functions are linear in output space, and that H and Q are the same, price and marginal cost may be defined as follows:

$$P_k = a - b \cdot Q_k \qquad \text{...11)}$$

$$MC_k = c + d \cdot Q_k \qquad \text{...12)}$$

where a and c are scalars and b and d are row vectors; Q are quantities of the k^{th} product.

Given these definitions and following procedures suggested by Samuelson (1947), it is possible to formulate conditions of equilibrium as those of an extremum (McCarl and Spreen 1980). However, this step is based on two assumptions: (a) the demand and supply functions are integrable, and (b) the demand and supply functions are independent of sector activity, i.e., the model must reflect a partial equilibrium. The substitution of product-demand function with product price and cost function with cost coefficients transforms the objective function for an individual given in equation (1) into an aggregate objective function shown by

$$\text{Max } Z^* = \int P_k \cdot \delta Q - \int MC_k \cdot \delta Q$$

$$= \int (a - b \cdot Q)\delta Q - \int (c + d \cdot Q)\delta Q \qquad \text{...13)}$$

subject to

$$\Sigma A_{esl} \cdot H_{jsl} \leq A_e \qquad \text{...14)}$$

The objective function in equation (13) is convex (or quasi-convex) in the output range. Its value gives a measure of consumer plus producer surplus. The sum of these surpluses, constituting the net social benefit (Samuelson 1952; Takayama and Judge 1971), is defined as the area between the demand and marginal cost curves to the left of their intersection (Fig. 3.2).

The price endogenous mathematical programming model for a fishery sector discussed above can be characterized as a simulation of industry behavior under the assumption of competition. The constrained optimization model takes as data production coefficients (A_{js}), and demand and supply (marginal cost) functions for outputs. The solution to the model generates equilibrium prices and quantity of outputs, and factor inputs.

In deriving the model it is assumed that the sector is composed of many competitive micro units, none of which can individually influence output or factor prices. Under appropriate management each producer would supply according to the rule: equate product price to marginal cost of producing one more unit of that product. Thus, the sectoral supply schedule will be an aggregate marginal cost schedule and *vice versa*. Similarly, each producer uses purchased factors according to the rule: equate factor price to its marginal value product. Thus the sectoral derived demand for factors will be an aggregate marginal value product schedule. These schedules can be derived or projected internally based upon production possibilities, output demand, and factor supply (McCarl and Spreen 1980).

Finally, the competitive behavior simulating properties of the model provides a potentially powerful tool for policymakers. The model allows the policy analysts to specify a change designed to meet some governmental objective, and then observe simulated sectoral response to the policy change. Such analysis can be done through validation of the model for base periods and updating based upon projected shifts in supply and demand, then simulating response to changes induced by policies. The model does not assume that sectoral participants will respond to what the government "wants"; rather, each producer optimally adjusts so as to maximize profits. Furthermore, producer adjustment is endogenous to the model (McCarl and Spreen 1980).

Linear Programming (LP) Approximation

The model maximand in the transformed objective function, shown by equation (13) is nonlinear in Q. However, for linear programming approximation the technique described by Duloy and Norton (1975) can be used. The method is applicable for both marginal cost and demand functions which are assumed independent by species/fishery (in the case of cost) and by-product forms (in the case of demand). In order to set up the LP Tableau, the linear approximation procedure involves direct segmentation of the functions representing the objective function (Agüero 1983, 1987; Hazell and Norton 1986). Each segmented function can be decomposed into several arbitrary subactivities in the LP Tableau (Table 3.1).

Table 3.1. A schematic of the LP Tableau for riverine fisheries of Bangladesh.

Max NSB	Harvesting (Cost)					Postharvest handling (Cost)			Retail demand (Benefit)			RHS
Obj. coeff. variables	$-H_{ijl1}$ X_{ijl1}	... ...	$-H_{ijlN}$ X_{ijlN}	0 Q_{ijl}	0 Q^a_{ijl1}	$-C_{irk1}$ G_{irk1}	... ...	$-C_{irkB}$ G_{irkB}	W_{ik1} D_{ik1}	... ...	W_{ikV} D_{ikV}	
Catch	q_{ijl1}	...	q_{ijlN}	-1								= 0
By-catch	q^a_{mijl1}	...	q^a_{ijlN}		-1							= 0
Convex set	1	...	1									<= 1
Biomass				1	1							<= Y_{ijl}
Effort	f_{ijl1}	...	f_{ijlN}									<= E_{il}
Product bal.				$-_{ijlr} \cdot \beta_{ijlk}$	$-\alpha_{ijlr} \cdot \beta_{ijlk}$	Q^*_{irk1}	...	Q^*_{irkB}				<= 0
Convex set						1	...	1				<= 1
Demand bal.						$-Q^*_{irk1}$	...	$-Q^*_{irkB}$	F_{ik1}	...	F_{ikV}	<= 0
Convex set									1	...	1	<= 1

Notations:

H = total harvest cost
C = total postharvest cost
W = total gross benefit
N = segments on total harvest cost function
B = segments on total postharvest cost function
V = segments on total benefit function
X = segment variable for harvest cost function
G = segment variable for postharvest cost function
D = segment variable for benefit function
Y = available fish biomass
E = total available effort
α = fraction of catch handled by each region
β = fraction of catch going to each product form
where
$\Sigma\alpha_{ijlr} <= 1$, $\Sigma\beta_{ijlr} <= 1$ and $\Sigma\Sigma\alpha_{ijlr} \cdot \beta_{ijlr} <= 1$

i = species (1, 2, 3, 4, 5)
j = river group (1, 2, 3, 4)
l = season (1, 2)
r = region of postharvest handling (1, 2, 3)
k = product form
m = species harvested as by-catch (1, 2, 3, 4, 5)
q = direct catch
q^a = by-catch
Q = total harvest of target species
Q^* = quantity of regional share at postharvest
F = retailed quantity
f = effort corresponding to harvest cost segment
Q^a = total quantity of by-catch

Fig. 3.3 illustrates the decomposition procedure for the benefit segment of the objective function. The curve in the upper diagram (A) of Fig. 3.3 is a downward sloping linear demand function. The integral of the demand function, shown in equation (13), is a benefit function labeled as W in the lower diagram (B) of Fig. 3.3. The curve W in diagram B is decomposed into six subactivities covering the whole range of the demand function in the diagram A. The coefficient of each subactivity is an area under the demand function corresponding to the Q defined by the subactivity. Similar methods can be applied to determine the subsegments of each of the cost segments in the objective function. The segmented activities approximating the nonlinear objective function is linear in its segment variables and can be readily solved by using the LP technique. Logan (1984) discussed the necessary convexity conditions that need to be satisfied in the linear approximation process of the individual functions as well as their aggregates in terms of objective function and constraints.

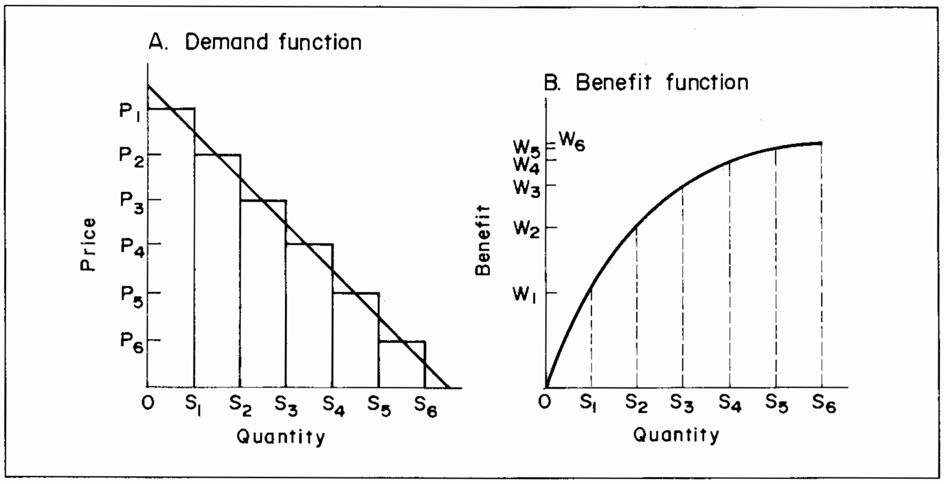


Fig. 3.3. Segmentation of demand and benefit functions for linear programming approximation (adapted from Duloy and Norton 1975).

The Riverine Fisheries Model of Bangladesh

General Characteristics

The mathematical model developed in this chapter takes into account simultaneously the various forms of interdependence that results from the biology of the resource and technology and market interactions. Specifically, the model includes: (i) relationships between catch, effort and stocks of various species and their interactions in terms of joint harvesting and/or by-catch ratios; and (ii) market interactions.

The objective of the model is, therefore, to assess the maximum benefit that the fisheries are capable of generating under different biotechnoeconomic and policy alternatives. The distribution of benefit between consumers and producers can also be evaluated in terms of the outcome of the model.

It must be noted that this model does not include any relationship linking parental stock sizes to subsequent recruitment and hence yield. Thus, the model cannot be used to predict or account for reductions of yield due to recruitment failure. We shall return to this point when evaluating the output of the model.

Objective Function

To represent the fishery process and evaluate economic effects of alternative management/policy interventions in the riverine fisheries of Bangladesh, the goal of fisheries management has been represented in terms of maximizing the NSB which is the sum of producers and consumer surplus. The management problem is to make the NSB as great as possible (maximize) without violating the restrictive conditions (constraints) imposed by the system. The function has been expressed in terms of physical output.

Activity Set and Constraints

The model consists of several blocks each representing an activity or set of activities with corresponding constraints. Some activities are artificially created (pivots) in order to facilitate the sequential flow among activities and/or to calculate values of certain variables determined by the model (e.g., producers income, total input use, etc.).

Activity set and constraints can be grouped into three blocks: harvesting, postharvest handling (processing, transporting, storing and marketing), and selling (retail demand). These blocks represent biological, technological and market characteristics, and interdependencies across species, space (region) and time period of fishing (season in this case) and environment (different fishing grounds and/or rivers in this case).

HARVESTING BLOCK

This block represents the dynamics of fishery production, its relationship with fishing effort and associated cost.

1. *Activities*: Harvesting activities represent the cost of fishing for each of the target species with associated by-catch relationships. The cost function reflects the inverse relationship between fish catch and fishing effort. The bioeconomic relationships convert cost per unit of effort into cost per unit of output. They consist of cost coefficients of catch and the technology matrix of effort per unit of catch for each species. Each successive unit of catch is drawn up from the available biomass at a higher level of effort, and hence at a higher level of cost. The harvesting activities define points on the upward sloping marginal cost curve defined as the integral of one independent species of fish. Cost of catch refers only to the catch of the target species. Production of by-catch (species other than the directed species) is external to each directed fishery (species). Therefore, they are considered free and costless in each directed fishery.

The activities in this block consist of (i) catch (representing direct harvest cost), (ii) by-catch and (iii) total catch activities. The latter two are pivot activities representing transfer activities for accounting and linking with other blocks of the model (e.g., postharvest handling and retail selling).

In the LP framework the catch activities are composed of a set of subactivities (segments) representing different values per unit of catch defined by corresponding segments of the bioeconomic production function. The number of segments defined for the subactivities is arbitrary and may be expanded to approximate the function (see Fig. 3.3 for segmenting procedure).

Externalities imposed by by-catch of one species on the cost per unit of catch of the other is also accounted for in the model in terms of by-catch activities. Each unit of principal species will accompany a ratio of by-catch of other species (expressed in terms of a coefficient) which will be treated as by-catch activities for the respective species. However, the by-catch will be drawn from the stocks of species which are also vulnerable to catch as a target species. Since each species is subjected to exploitation both as a target species and as by-catch, such a relationship will exhibit technological interdependencies affecting the cost of one species while increasing fishing effort on the other species.

2. *Constraints/Restrictions*: Constraints defined for this block are the biomass or stock of each species, by-catch ratios, harvest limits (catch-by-catch balance), convexity conditions and effort restrictions. The biomass and effort restrictions represent the biological and economic relationships derived in the bioeconomic submodel (see next section).

Given that there are i different species of fish harvested from j different fishing environments or grounds (rivers/group of rivers) in l different seasons over a year, the activities representing the total annual cost of harvest (TC_1) in the objective function can be expressed as

$$TC_1 = \Sigma\Sigma\Sigma\Sigma H_{ijln} \cdot X_{ijln} \qquad \text{...15)}$$

where H is the cumulative area under the harvest cost (marginal) function, X is the segment variables for the harvest cost function and n is segment of harvest cost function (n = 1, .., N)

Accordingly, the constraints for this block would include:

Direct catch:

$$\Sigma q_{ijln} \cdot X_{ijln} - Q_{ijl} = 0 \qquad \text{...16)}$$

By-catch:

$$\Sigma\Sigma q^a_{mijln} \cdot Xijln - Q^a_{ijl} = 0 \qquad \text{...17)}$$

Effort:

$$\Sigma\Sigma f_{ijln} \cdot X_{ijln} \leq E_{il} \qquad \text{...18)}$$

Available biomass (catch + by-catch):

$$Q_{ijl} + Q^a_{ijl} \leq Y_{ijl} \qquad \text{...19)}$$

Convexity:

$$\Sigma X_{ijln} \leq 1 \qquad \text{...20)}$$

where

- q = cumulative quantity of targetted species (direct catch) harvested by segment of harvest cost;
- q^a = cumulative quantity of by-catch of other species;
- Q = total quantity of targetted (direct) species;
- Q^a = total quantity of by-catch;
- f = cumulative quantity of effort required by segment of harvest cost function that corresponds to the rising portion of the yield-effort curve;
- E = maximum available effort;
- Y = maximum available biomass (allowable landings); and
- m = species harvested as by-catch.

POSTHARVEST HANDLING BLOCK

This block accounts for cost involved in processing, transporting and marketing between ex-vessel landings and retail sales. The activities represent postharvest total cost of output. The model assumes an increasing marginal cost for postharvest. The function can be derived from the difference between retail and ex-vessel demand functions (Tomek and Robinson 1981). The cost for each species can be separated by geographic region as well as product form. For each species the activity set represents the total postharvest cost (area under the marginal postharvest cost curve) corresponding to various segments of total output. The constraints in this block include distribution and balancing equations and convexity conditions. It should be noted that postharvest losses have not been considered in the model, for most of the fish species harvested from the inland open waters of Bangladesh are consumed fresh.

Given that each of the i^{th} species of fish harvested from r different regions is transformed into k different product forms during the course of processing, transporting, storing and marketing in the final retail market, the activities representing total postharvest cost (TC_2) in the objective function can be expressed as

$$TC_2 = \Sigma\Sigma\Sigma\Sigma C_{irkb} \cdot G_{irkb} \qquad \text{...21)}$$

where C is the cumulative area under the postharvest cost (marginal) function, G are the segment variables for the postharvest cost function and b are the segments of postharvest cost function (b = 1, 2, ..., B).

The constraints for this block will be

Harvest and postharvest balance:

$$\Sigma\Sigma\Sigma\alpha_{ijlr} \cdot \beta_{ijlk} \cdot Q_{ijl} + \Sigma\Sigma\Sigma\alpha_{ijlr} \cdot \beta_{ijlk} \cdot Q^{a}_{ijl} - \Sigma Q^{*}_{irkb} \cdot G_{irkb} = 0 \qquad \text{...22)}$$

Convexity:

$$\Sigma G_{irkb} \leq 1 \qquad \text{...23)}$$

where

α = fraction of total product k handled in region r;

β = fraction of regional catch going to product line (product form) k; and

$\Sigma\Sigma\alpha_{ijlr} \cdot \beta_{ijlk} = 1$

$\Sigma\alpha_{ijlr} = 1$

$\Sigma\beta_{ijlk} = 1$;

Q^* = cumulative quantity of regional share of fish catch by segment of postharvest cost.

SELLING BLOCK

Selling activities represent the demand function for each commodity/product. If the products are independent in demand (zero cross elasticity), the selling activities will represent the area under the demand curve corresponding to successive segments of demand (see Fig. 3.3). The coefficients of each activity will thus represent the total benefit to society from the level of demand represented by the corresponding activity. Thus, the activities represent points on a curve defined as the integral of one independent (in demand) fish product.

If the products are interdependent, implying substitution in demand (nonzero cross elasticity), the activities will represent points on the benefit surface (function) defined as the line integral over the quantities of two or more interdependent (in demand) species (Duloy and Norton 1975; Agüero 1983; Logan 1984).

Assuming independent demand functions for each of the k^{th} fish products from each species of fish, the activities representing the total benefit (TB) in the objective function can be represented as

$$TB = \Sigma\Sigma\Sigma W_{ikv} \cdot D_{ikv} \qquad \text{...24)}$$

where W = cumulative area under the demand function; D = segment variables for demand the function; and v = segment of demand function (v = 1, 2, ..., V).

The constraints applicable to this block will be

Sales balance:

$$\Sigma\Sigma Q^{*}_{irkb} \cdot G_{irkb} - \Sigma F_{ikv} \cdot D = 0 \qquad \text{...25)}$$

Convexity:

$$\Sigma D_{ikv} \leq 1 \qquad \text{...26)}$$

where F = cumulative quantity of product sold in the retail market by segment of demand function.

Given the above description of the different blocks, the model can now be specified to maximize the sum of total benefit (TB) minus total cost (TC1 + TC2), i.e.,

$$\text{Max } Z = - \Sigma\Sigma\Sigma\Sigma H_{ijln} \cdot X_{ijln} - \Sigma\Sigma\Sigma\Sigma C_{irkb} \cdot G_{irkb} + \Sigma\Sigma\Sigma W_{ikv} \cdot D_{ikv} \qquad \text{...27)}$$

subject to the constraints (16) to (20), (22), (23), (25) and (26). A schematic of the LP Tableau is shown in Table 3.1.

Model Parameters and Functional Relations

Continuous functional relationships have to be considered for harvesting, postharvest handling and retail selling blocks in the implemention of the model specified above. Accordingly, at the harvesting level, the functional relationships representing cost-output and effort-output are needed. Various levels of market demand (e.g., ex-vessel and retail demands) can be used to establish postharvest cost structure and retail prices. The difference between retail demand and ex-vessel demand would represent the postharvest cost functions. The retail demand function(s) represent(s) the benefit and/or revenue functions in the retail selling block.

Bioeconomic Production and Market Submodels

This section discusses the two important submodels that provide the basis for interaction of elements in the fisheries harvesting, postharvest handling and retail selling blocks in the programming formulation.

Bioeconomic Production and Fishery Supply

The supply function in fisheries originates in the production/harvest sector of the fishery, and it represents the response of the resource to fishing mortality. In other words, on the supply side, fishery production from a biological pool of resources is the direct outcome of relationships between catch and fishing effort. However, it is the market that finally absorbs the production and the relationship between price and quantity, known as the economic supply function, is established.

As such, it is important to give economic configuration to the biological production function (supply) through explicit pricing of factors that constitute the fishing effort. Nevertheless, no attempts have been made to formulate a direct functional relationship between a fishery production and effort in the sense of steady-state equilibrium. Rather, the relations consist of the identification of points in production space through the use of enterprise production models by means of aggregation.

The establishment of the production parameters, that is to say activity coefficients, is of central importance to the current modelling exercise. These parameters will provide the values of cost and effort parameters in the harvesting block of the programming model.

FISHERY PRODUCTION FUNCTION

Biological Production. The basic biological model of an unexploited fishery consists of a growth function that relates natural growth to the size (biomass) of fish population, where natural growth (G) is defined as recruitment (R) plus individual growth (D) minus natural mortality (M). Such relationship is exhibited in terms of the logistic growth function:

$$G = G(X) \qquad \text{...28)}$$
$$G(X) = \gtreqless 0 \text{ for } X = K,$$
$$\delta G/\delta X = \gtreqless 0 \text{ for } X = X_{max} \text{ and}$$
$$\delta^2 G/\delta X^2 < 0 \text{ throughout}$$

where G is natural growth measured in terms of biomass; X is size, also measured in terms of biomass; and K represents the level of natural equilibrium of the stock or carrying capacity of the environment.

Bioeconomic Production. The fishery dynamics in an exploited fishery can be summarized as follows:

A fish population or stock is a pool of resources where a continuous process of recruitment, growth and mortality is at work. The joint effect of fishing mortality (F) and natural mortality (M) causes the population to decline in numbers. Population biomass increases or decreases according to the combined effect of individual growth and losses due to total mortality (Z = F + M). Under equilibrium, recruitment compensates for all losses in number and weight (Beverton and Holt 1957).

In an exploited fishery, the catch Y in any period will depend on the size of stock (X) and the amount of fishing effort (E) in that period. That is

$$Y = Y(X, E) \qquad \text{...29)}$$

This function is characterized by positive and diminishing marginal product of X and E. Thus, in the short run, for a given X, the larger the effort, the greater is the catch (Y). Conversely, for any given E, the larger the fish stock, the greater is the catch. One can have a family of short-run production (yield) curves, each defined for a particular population size. These are shown in Fig. 3.4, where the greater the population the greater will be the yield resulting from a given level of effort.

Combining equations (28) and (29) and setting Y = G, gives:

$$X^* = \phi(E) \qquad \text{...30)}$$
$$\delta\phi(E)/\delta E < 0 \text{ and } \delta^2\phi(E)/\delta E^2 < 0$$

where X^* is the population equilibrium size, i.e., the fish stock corresponding to a catch that is equal to natural growth ($Y^* = G$). Equation (30) represents the population equilibrium curve (Panayotou 1985).

Substituting equation (30) in equation (29) gives the yield effort curve or the sustainable yield equation (31)

$$Y^* = F[E, \phi(E)] = F^*(E) \qquad \text{...31)}$$

where Y^* is sustainable yield in the sense that $Y^* = G$ and that corresponding fish stocks remain unaffected by fishing (as long as E remains constant).

The following properties hold for equation (31):

(a) $\delta F^*/\delta E > 0$ for $0<E<E_{msy}$
(b) $\delta F^*/\delta E = 0$ for $E=E_{msy}$
(c) $\delta F^*/\delta E < 0$ for $E>E_{msy}$

Any point on $F^*(E)$ gives a sustainable yield, i.e., a catch that is equal to natural growth of the corresponding fish stock, which can be maintained as long as effort remains unchanged.

The representation in equation (31) gives the long-run steady-state yield (production) function of a fishery. Although the fish stock size or resource abundance varies among fishing grounds and time periods (seasons), in the short run, under a defined seasonal context, the fish stock (X) in a particular fishery will be here assumed to be constant. This allows estimation of the production function of the simple form given in equation (32).

$$Y = E(E) \qquad \text{...32)}$$

where Y = catch and E = effort (index).

FISHING EFFORT AND ITS INTERNAL STRUCTURE

The concept of fishing effort occupies a central position in fisheries economics literature. This is due to the emphasis given by management regimes to regulate one or more of its components as management tools (Clark 1976; Anderson 1977; Scott 1979). The term fishing effort in equation (32) is a composite input, often broken down into its typical elements such as labor, capital, material and time spent. These elements can be further decomposed depending on the nature and the type of fishery. For example in small-scale and traditional nonmechanized fishing, it is boat and gear that make up the major capital, as opposed to engine, power block, refrigeration facilities and fishing aids along with vessel and gear that constitute the major elements of capital in large-scale industrial fishing.

The amounts of all the capital components mentioned above, plus labor (assuming a fixed crew size) determine the catching power of a fishing unit, whereas the time spent in fishing determines the rate of utilization of existing fishing capacity. If a variety of fishing gear is used, it may be necessary to classify fishing units by type of gear used, as they represent different fishing strategies and hence different catching power. For instance, the use of push nets, trawl nets, gillnets, seine nets, hooks and line etc., may all represent different catching power in the context of a particular fishery.

In fact, the operators of a fishing unit combine capital (K), labor (L), materials (M) and managerial skill (N) to produce catching power, which when multiplied by time (h) spent in fishing gives the total amount of effort expended. This gives:

$$E = E(K, L, M, N,)h \qquad \text{...33)}$$

The variable effort in equation (33) is typically part of an input combination process. Often, factors of production are combined to form a composite input index of effort, which becomes an input in the fishery production function (Anderson 1976; Squires 1987). However, direct estimation of the effort through use of specifications similar to equation (33) may not always be practical.

Production Models for the Riverine Fisheries of Bangladesh

IDENTIFICATION AND DEFINITION OF VARIABLES AND MODELS

The formulation of a production model for these fisheries requires the identification of the important variables that define fishing effort and subsequently determine yield. They include: (i) population size of different species and their periods of abundance; (ii) type of environment and their geo-physical features; (iii) type, size and other characteristics of boat and gear; (iv) the number of fishers, time spent in fishing and their skills; and (v) intensity of fishing over season (i.e., length of fishing period/season).

The major groups are hilsa, carp, catfish and prawns, constituting 62% of the average annual catch, hilsa alone being 44% (Table 2.2). Moreover, the distribution of these species seems to follow spatial and seasonal patterns as described earlier. Although groups other than the above do not individually constitute a separate fishery, their aggregate can do so. Fishers who catch these mixed species rather than the four major groups are found everywhere. As such, these species can be said to constitute a fifth fishery based on "miscellaneous species".

Although boat characteristics do not differ across fisheries except in size, the types of gear used and their size exhibit wide variation as stated in Chapter 2.

As regards fishing labor, its size and skill depend on the size of boat and gear and type of gear used. Usually fishers spend more hours in fishing during the peak months of harvest than in lean months. In addition, there are other factors that contribute to the harvesting process, such as floats and weights for keeping nets upright, sails of a boat, lanterns and flashlights, deck facilities, etc.

Given the above description on the variables defining effort and determining the resultant fish production from the inland open waters, a traditional functional relationship for each individual species i at time t can be shown by equation (34)

$$Y_{it} = f(S_{it}, A_{it}, B_{it}, R_{it}, L_{it}, O_{it}) \qquad \text{...34)}$$

where i = species (group); t = time; Y = tonnage of harvest; S = fishing season; A = river and/or fishing ground); B = boat capacity; R = gear capacity; L = fishing crew; and O = other inputs (floats and weights, sail, lanterns, flashlights, etc.).

The variables on the right hand side of equation (34) can also serve as factors that define an effort index similar to that in equation (33).

SPECIFICATIONS OF THE ECONOMETRIC MODEL

In the absence of confirmed biological knowledge of the number and stock size of each species group and their distribution across water areas (or rivers) and over seasons, fluctuation as well as the spatial differences in both absolute and relative harvest of each group can serve as a basis for making seasonal and spatial distinctions. Thus, the production models are separated by seasons (dry and wet season) and rivers (four river groups). The separation of fisheries in terms of two seasons is consistent with the fishing calendar followed by both management authorities and fishers. The grouping of rivers in terms of three principal river systems and other small rivers is also consistent with the grouping followed by the Fisheries Resource Survey System (BFRSS) of the Department of Fisheries (DOF).

While fishing seasons (S) and rivers and/or fishing grounds (A) are distinguishable in the manner discussed above, variables B, R and O require further specification. Since the boats vary in length, width and draft, they all are considered as principal determinants of boat capacity (B). However, these parameters usually follow a definite proportion, and they might give rise to the problem of multi-collinearity when used as independent variables in an econometric estimation model. A single measure to represent boat capacity could be the total volume (length x width x draft) or tonnage. Khaled (1985) used tonnage of boat capacity and found it significant in estimating the production technology of hilsa fishing in the Meghna and Padma Rivers.

Similarly, capacity of a gear (G) depends on the type of gear (net type, hook or lines), length, depth and mesh size (in case of net) and number of hooks and their size (in the case of hooks and lines). Therefore, these parameters of gear should also be treated as determinants of production. However, mesh size of net is found to be typical for a particular target but varies over seasons where the size of fish caught is different. For instance, the size of hilsa caught during the dry season is smaller than that caught in the wet season. As such, mesh size would not be significant in explaining production differentials (Khaled 1985). On the other hand, to capture differences in net type, either dummy variables or a standard unit of gear can be used, while the size of net can be measured by the surface area (m^2) of the net.

As for the other inputs (O), most (e.g., sail, floats and weights) are proportional either to the size of boat or to size of net. Hence they can be excluded from the function.

The catch quantity (Y) includes only that of the target species. Other species would be treated as by-catch obtained from the effort directed to the major species groups being modelled.

Thus, an econometric model for seasonally and spatially (rivers) distributed target groups can be further specified as

$$Y_{irst} = f(B_{irst}, R_{irst}, L_{irst}, D_{irst}, H_{irst}, U) \qquad ...35)$$

where i = groups (1,2,..,5); r = river (1,2,3,4); s = season (1,2); t = time (year); Y = tonnage of production; B = tonnage of boat(s); R = surface area of net(s); L = size of crew; H = fishing time (hours); D = dummy variable for gear type; and U = error term.

The functional relation in equation (35) is a multiple-input production function. As such, effects of changes in the effort intensity on fishing mortality are only partially represented by changes in each of the individual factor inputs. A single relation of production and effort, is therefore, more useful for explaining the fishery dynamics. As mentioned earlier, effort in equation (32) translated in terms of component factors in equation (33) is an index and, as such, gives a single measure of effort. However, the measurement of an index through equation (33) may give biased results if the relative weights of individual factors and their variants are arbitrary. The use of a single real economic factor that can serve as an indicator of fishing power as a measure of effort is more appropriate. Also, factor inputs both in equations (33) and (35) may follow a definite proportion in producing effort as well as output, thereby exhibiting a high correlation between each other.

Considering the above, fishing gear capacity (defined below) has been chosen as a measure of effort in the current framework. This variable appeared more relevant in defining the fishing power of an individual fishing unit as well as that of the fleet in the concerned fisheries, although it is the boat that normally defines a fishing unit and holds the fishing crew, gear (nets or hooks) and other material on-board while fishing. The Fisheries Resource Survey System initiated through the FAO/UNDP used gear as a unit of effort (Tsai and Ali 1985).

Usually, boat and crew size are weak indicators of fishing power in small-scale multispecies and multigear fisheries (Prof. H.C. Lampe, pers. comm.). The size of crew follows a proportionate relation to the size of gear in a particular fishery at a given time. That proportion can, however, change independently of gear size depending on the opportunity cost of labor and overall economic situation in the country.

Similarly, boats of a certain size-range are found to operate with a wide range of gear capacity. This is because gear is a less durable and more highly depreciable asset than a boat, and investment on gear depends on the financial strength of the individual fishing units. In essence, it is the size and capacity of gear (including the time spent in fishing) that makes a marked distinction between the fishing power of individual fishing units.

Given the gear capacity as the single explanatory variable determining the production, the input-output relationship in equation (35) reduces to a more useful yield-effort relationship similar to equation (32), this time with a unit measure of effort. However, rather than the total tonnage of harvest the dependent variable could as well be the catch per unit of effort (CPUE) shown in terms of equation (36).

$$CPUE = G(E) \quad \textbf{...36)}$$

where CPUE = catch per unit of effort; and E = total fishing effort (gear capacity).

GEAR CAPACITY AND METHODS OF STANDARDIZATION

Gear capacity is defined as:

$$G = S \times T$$

where S = surface area of the net(s), = length/piece x width (depth) x no. of pieces of net; and T = total fishing hours during the season, = total days of fishing x average fishing hours per day.

The above definition of gear capacity will not hold good for all types of gear used in a particular fishery. In standardizing the effort (gear capacity) of each species I have assigned the fishing gear that catches the major portion of the catch as the standard. The efforts of all other gear are expressed in terms of the dominant gear by dividing their gross catch by the average CPUE of the dominant gear (Tsai and Ali 1985).

COST FUNCTION

The cost component for the harvest of each group of fish in the objective function of the programming model is expressed in terms of fish catch. This will require the derivation of a cost function in terms of fish catch (yield) as shown in equation (37).

$$ACq = q(Y) \qquad ...37)$$

where ACq = average cost per unit of catch; and Y = total catch.

However, the bioeconomic production function, i.e., catch and effort relationships and market cost or opportunity cost of effort, has a direct bearing on the unit cost of fish output (Copes 1970; Anderson 1977). For a given level of population size or fish stock

$$AC_q = AC_e/CPUE \qquad ...38)$$

where AC_e = cost per unit of effort.

The definition in equation (38) assumes a constant cost per unit of effort and a declining CPUE as effort expands. Therefore, one would expect an increasing cost per unit of catch, making equation (37) an increasing function of catch (Y). In a long-run perspective, this function increases until the maximum sustainable yield is reached and bends backward (decreases) thereafter. However, different levels of population would give different cost curves each representing a particular short-run situation. Fig. 3.5 shows a family of short-run total cost curves, whose derivation can be made direct from the short-run yield curves given earlier in Fig. 3.4.

The ranking of population in Fig. 3.5 is reversed (from Fig. 3.4), in the sense that the smaller the population, the more it costs to achieve any given yield (Cunningham et al. 1985). Since the short-run total cost of an output curve increases at an increasing rate (Fig. 3.5), both short-run average and marginal cost curve would also increase (Fig. 3.6).

Each set of short-run cost curves is defined for one population level only. Thus, a change in the population size will shift the fishery to a new set of curves. A fall in population will result in an upward shift of curves while an increase will shift them downwards. Considering the growth phases of a fishery as similar to the movements of population to different sizes over time these short-run curves could be made to reflect the various stages of its exploitation phases.

In the long run, considering a steady-state situation for the fishery, however, the cost function will increase up to the catch limit of maximum sustainable yield and bend

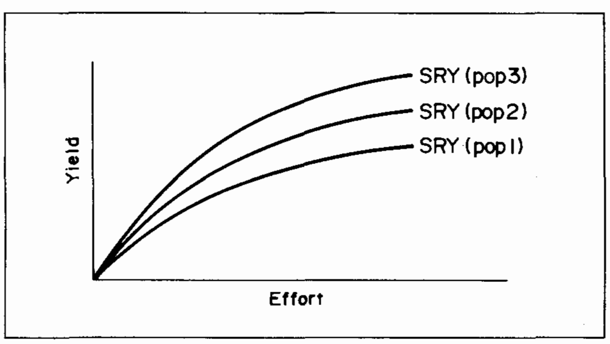


Fig. 3.4. Short-run yield curves as a function of nominal efforts (adapted from Cunningham et al. 1985).

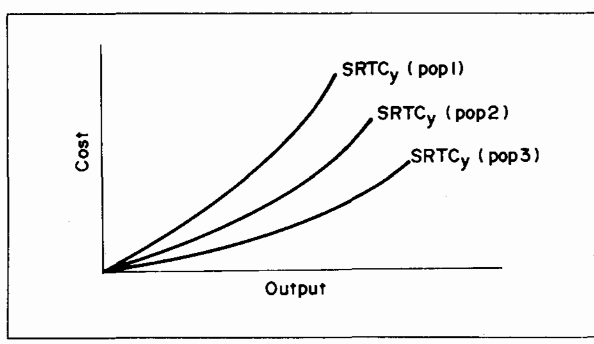


Fig. 3.5. Short-run total cost as a function of fish output.

backward thereafter, implying a decline in the steady-state harvest as further expansion of effort takes place. This is shown in Fig. 3.7 where the backward bending curve AC is the long-run average cost curve in terms of fish catch for the fishery as a whole. It can be derived directly from the sustainable yield curve and the total cost curve for effort (Anderson 1977).

The short-run curves also play a part in determining the path of the long-run curve. The curves labeled AC_{p2} and AC_{p1} in Fig. 3.7 show how the average cost per unit of fish varies with output at two different population sizes (Anderson 1977). These curves imply that the average cost of fish will increase as catch gets larger. Moreover, the cost curve for the smaller population size (P_2) is higher than the one for the larger population size (P_1).

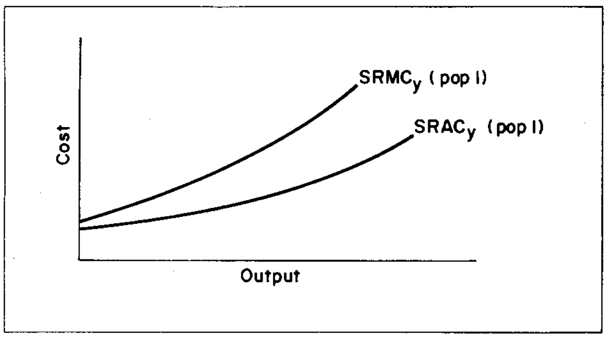


Fig. 3.6. Short-run average and marginal cost curves for fish output.

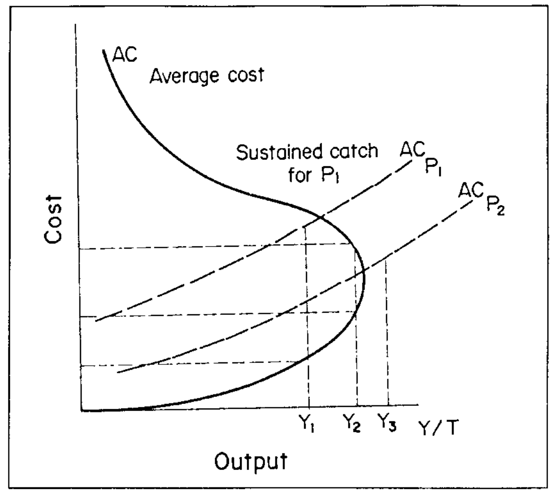


Fig. 3.7. Long-run average cost curve of fish output in a steady-state fishery.

These short-run curves will intersect the long-run cost curve at the sustainable yield for the given level of population. Conversely, on each short-run average cost curve there will be one point that could continue into the long run. The long-run average cost curve is then the locus of all such points (Cunningham et al. 1985).

COMPONENTS OF COST

Cost for a given fishing unit comprises fixed and variable cost. Variable cost includes: labor, fuel for lanterns and batteries for flashlights, food, maintenance and repair of boat and gear, purchase of nondurable goods, and fishing license fee or toll.

In a given fishing period, variable costs can be defined straightforwardly as the sum of cost of all inputs that are incurred when the fishing unit operates. Quantitatively, the most important costs in the case of nonmotorized inland fisheries in Bangladesh are those spent on labor (including food) and replacement and maintenance of nets. Normally, nets are considered fixed inputs. However, in a given season they are replaced wholly or partly for reasons such as high rate of wear and tear and accidental losses (Khaled 1985). Therefore, maintenance cost of nets appears quite significant.

Traditionally, fixed costs include: interests on borrowed funds and rentals for capital items, and depreciation and opportunity cost of own capital (e.g., boat, gear).

Interest payments on borrowed funds are quite significant in the case of riverine fishing in Bangladesh. Normally, in the beginning of the fishing season a large amount of working capital is required to prepare the unit for fishing operations. This capital is used to buy the nondurable items like utensils, stoves, lanterns, flashlights, etc., to repair the gear and boat and their complements, and to buy additional gear to increase the fishing capacity of the unit. The source of such capital is from usury sources (private moneylenders or fish traders), and they usually charge a rate of interest ranging from 8 to 10% per month (BCAS 1987).

To calculate depreciation (d), the purchase price or capital cost (P_k) of such fishing assets such as boats, anchors and nets, their economic life (L) and their scrap or salvage value (S) are needed.

However, calculation of depreciation for boats or nets is not important as a component of cost in the context of fishing. In fact, in fishing operations constant repair and maintenance keep the asset almost equally productive for a longer time than contemplated in the approach of depreciating the asset at a certain rate. Moreover, if proper repair and maintenance costs are included in the calculation of cost, inclusion of typical depreciation allowances may result in double counting.

Aside from these, there is a wide range of variations in the structure of fishing costs, delivered through several channels; modes of payment for each of them vary across fishing unit and fishing ground. Important among them are labor and capital items. In terms of the previous definition of cost, labor cost is treated as a variable cost. This assumes a fixed wage rate, similar to that of hired labor in agriculture. However, in practice, it is common for the crew to be paid a share of the value of catch instead of the fixed wage rate. In addition, among individual crew members, payment or share varies according to skill and role in the fishing process. This procedure applies to owner's labor also, and thus makes such cost a real one.

Similarly, if capital items such as boat and gear are rented by the fishing unit, payment is made most of the time in terms of a share of catch, instead of cash rents. This is a common practice when the crew members provide some of the capital items to be used by the fishing units.

The Market Submodel

A quantitative analysis of demand-supply and price relationships of different species of fish is necessary to provide an appropriate price mechanism in the programming model. The parameters of econometrically estimated functions are required as inputs into the programming model to determine solutions to the market model simultaneously with the other submodels (technological and biological).

The price analysis will provide two important informations: (i) specific economic coefficients (parameters) such as price and income elasticities (or flexibilities) of demand (or prices); and (ii) forecasts of prices or variables affecting prices.

The model was conceived at three levels, i.e., ex-vessel, wholesale and retail markets between the fishers and the consumers in terms of important determinants, although the model for wholesale market could not be estimated because of lack of data. Effort was made to isolate and demonstrate spatial differences and seasonal changes in the demand for each of the fish species, especially at the ex-vessel level. The model contains equations wherein the functional relations of the major determinants of supply and demand are postulated.

EX-VESSEL MARKET

The ex-vessel market refers to the market where fishers deal with the first buyers. The buyers are mostly assemblers or collectors. The process of collecting is confined to the area comprising the fishing grounds up to assembly points or landing sites. A large number of nonmotorized (a few motorized) boats are engaged in collecting fish from the small fishing units scattered over the fishing grounds in the riverine waters in different regions of the country. The conduct at this level is rather simple. Harvested fish are channelled to the assembly point by a group of middlemen (agents) whose numbers are more or less limited, having some informal agreement with the harvesters with regard to the transaction.

Variables that reflect behavior of price in this market are: the level of harvest, their size and quality, the fishing ground, cost of transportation, existence of landing stations and their proximity to the fishing grounds, weather conditions affecting harvesting activity and seasonal abundance of harvest.

Although markets are separated between locality or area of fishing and hence prices of individual fish species in each market would differ, the free flow of information among markets can easily act against marked price differential among small local ex-vessel markets.

The existence of a strong seasonality in the abundance and availability of various groups of fish in different fishing grounds would also influence the pricing of fish in each market. This might give rise to separate seasonal markets at the ex-vessel level reflecting seasonal differences.

Distinction between markets can also be made by region as there are important differences in the availability and abundance of species in each region as well as final demand conditions.

Another factor that could affect the pricing mechanism is the market power of buyers (collectors) and sellers that determine the degree of competition in each individual market. At the ex-vessel market buyers are able to exert some extra-economic power on the sellers because of credit ties, the buyers being the suppliers of capital for fishing to the sellers (fishers). The existence of such force could possibly distort the competitive pricing process. However, as the numbers of buyers and sellers become large and there is better flow of information between markets, the distorting forces become weaker. The same is true in the long-run, whereby forces of competition would correct such distortions.

Also, if the flow of information on prices and harvest is perfect, the prices prevailing in other areas affect the price in a particular market and vice versa. The distance between the area of fishing and the landing center also affects the price through its effects on communication means, transport cost, postharvest handling and freshness. However, if the flow of information is perfect and complete among markets, other things remaining the same, the prices in each market will only differ by the extent of transport costs.

Since the demand at the ex-vessel market is derived from the upper markets (wholesale and retail), the prices in the upper markets, especially the wholesale price, directly influence the price in the ex-vessel market.

On the demand side, a particular ex-vessel market price at any point in time (t) would generally depend on the landings. As stated earlier, the production (supply side of the fishery) being dependent upon various exogenous factors, it is the quantity demanded that determines the price, at least in the short run. As such it is more logical to conceive the demand in terms of price (Farrell and Lampe 1965; Waugh and Norton 1969; Wang 1976; Bockstael 1977; Storey and Willis 1978; DeVoretz 1982; Wang et al. 1978, 1986; Cook and Copes 1987).

Thus, separating markets by species, locality, landing center, fisheries region and seasons of fishing we can state the ex-vessel demand prices (Pv^d)as:

$$Pv^{d}_{ijklmt} = f(Q_{ijklmt}, S_{ijklmt}, P_{o \cdot xjklmt}, P_{w \cdot ijklmt}) \qquad \text{...39)}$$

where i = species
j = locality/ area of fishing
k = landings market
l = fisheries region
m = season of fishing
t = time period (a month)
Q_i = landing quantities of the species
S_i = size (or weight) of landed species
$P_{o.x}$ = composite prices of other species
$P_{w.l}$ = average price of species (i) in the upper (wholesale) market(s).

The supply side of the market for fish at the ex-vessel level needs special explanation. Unlike many other industrial and agricultural commodities, the supply of fish in the short run is governed more by biological, environmental and technological factors than by price. Such factors are dominant in the short and medium run. Moreover, fish are usually marketed fresh. As such, the important determinant of supply is the current rate of fishing mortality and past history of mortality rates, which in turn are determined by the aggregate level of effort devoted to fishing and also on catchability coefficient (Lampe 1967). If the level of fishing does not change (which is likely in the short run), the supply is predetermined by natural factors in a particular ex-vessel market.

In the long run, however, supply (harvest) of a fish species will be affected by its price, prices of other species, prices or opportunity cost of inputs (effort) and productivity of inputs (amount of effort per unit of output).

The ex-vessel supply (Qv^s) of a particular species (i), in a particular local ex-vessel market (j), within a landing center (k), region of fishing (l), season (m) and at time period (t) can, therefore, be regarded as predetermined as shown in equation (40).

$$Qv^s_{ijklmt} = A_{ijklmt} \qquad \textbf{...40)}$$

where 'A' is a predetermined value of landings of species (i), which is the outcome of several exogenous natural and physical factors. Hence, the supply price is perfectly flexible with respect to given quantities of ex-vessel landings.

The above formulation assumes separate markets for each locality or area of fishing. As such, markets are considered relatively thin and are confined to a limited number of buyers and sellers who are isolated from their counterparts in other areas. However, if one considers the free flow of information on price, landings of species and other variables affecting price relations, these small markets could be aggregated into one single market over a region or at least over a landing center for wholesale trading. This generalization appears more realistic as discussed in the next section (section on wholesale market) in that the market operating between the fishers and assemblers/ collectors is part of the same market based in the landing centers or docksides. In fact, the collectors/ assemblers are in most cases the commission agents or buying agents of the fish traders based in the landing centers or dockside markets (FAO/Rapport 1986).

Based on the above generalization the specification of demand and supply model within the regions can be simplified.

WHOLESALE MARKET

At this level demand is broad with alternatives available. Moreover, the market is stretched in a long chain (vertical and horizontal) of intermediaries spread all over the region/country dealing with the fish before it goes to the retail market.

The chain of marketing immediately after the first level of wholesale (sale by the assemblers or collectors) is complex, involving movement across regional boundaries and changes of intermediaries and dealers. Therefore, the number of variables that enters into the market clearing process can be quite large depending on the stage of wholesale in the marketing chain in the course of horizontal and vertical movement of fish. Important among them are: prices (including other species), net amount of fish available for wholesale (including other species), regional location of fishing and markets, distance between assembly point and wholesale market, type and extent of postharvest handling operations, means of transport and its cost, regional preference for the species, prices in the retail market and seasonality.

Although markets at the wholesale levels consist of two submarkets and several intermediate stages performing marketing functions they can be simplified into one level by treating the first level wholesale market (i.e., the transaction between collectors or assemblers as part of the ex-vessel market and subsuming the other intermediate market levels into the final wholesale market (urban or suburban wholesale markets) along the chain as transportation and commission service activities.

Even though supply at the ex-vessel level is predetermined, at the wholesale level it would be considerably affected by price, as the amount of fish inflows and outflows to and from each region will respond to price movements. The net flow (regional import - regional export) will be a function of price. Therefore, at the wholesale level the net supply quantity (which is different from landing quantities) will become a determinant of price or vice versa.

Given the above simplifications the wholesale price equations for demand (P_w^d) and quantity equations for supply (Q_w^s) for a species (i), in region (l) and season (m) can be represented by equations (41) and (42).

Demand:

$$P_{w\ ilmt}^{d} = f(Q_{wilmt}, S_{ilmt}, P_{wxlmt}, P_{rilmt}, N_{plt}) \qquad ...41)$$

where
- i = species
- l = region
- m = season of fishing
- t = time period (a month)
- Q_{wi} = quantities of the species (i) demanded
- S_i = size of species (i)
- P_{wx} = composite prices of other species
- P_{ri} = price of species (i) in the upper (retail) market
- N_p = size of population

Supply:

$$Q_{w\ ilmt}^{s} = f(P_{wilmt}, P_{wxlmt}, P_{rilmt}, P_{wizmt}) \qquad ...42)$$

where
- i = species
- l = region
- m = season of fishing
- t = time period (a month)
- Q_{ws} = Q[(landings) + M(import) - F(export)]
- P_{wi} = price of species (i)
- P_{wx} = composite prices of other species (x)
- P_{ri} = price of species in the upper (retail) market
- P_{wz} = wholesale price of species (i) in other regions.

RETAIL MARKET

This market represents the primary demand (consumer demand) from which demands in the lower markets are derived. Transactions take place between retailers and consumers. At this level variables that are important determinants of supply-demand and price relationships are quantities and prices of fish and other substitute goods, income, population and taste. However, since individual retail markets are scattered and have considerable difference in terms of transport and communication as well as purchasing power of the consumers (e.g., urban and rural), distinct independent local or regional retail markets can exist.

In functional form the price equation for demand (P_r^d) and quantity equation for supply (Q_r^s) at the retail level can be represented in terms of equations (43) and (44), respectively.

Demand:

$$Pr^d_{ilmt} = f(Qr_{ilmt}, S_{ilmt}, Pr_{xlmt}, Pr_{almt}, Np_{lt}, In_{lt}, Cf_{ilt}) \quad ...43)$$

where
- i = species
- l = region
- m = season of fishing
- t = time period (a month)
- Qr_i = quantities of the species (i) demanded in the retail market
- S_i = size of species (i)
- Pr_x = composite prices of other species
- P_a = prices of substitute animal proteins
- Np = size of population served by the retail market
- In = personal income of consumer
- Cf_i = consumer preference for fish (i)

Supply:

$$Qr^s_{ilmt} = f(Pr_{ilmt}, Pr_{xlmt}, Pr_{almt}) \quad ...44)$$

where
- i = species
- l = region
- m = season of fishing
- t = time period (a month)
- Pr = price in the retail market
- Pr_x = price of other species
- P_a = price of other animal proteins

SPECIFICATION OF THE ECONOMETRIC MODEL

In the definition of general economic relationships in the previous sections we have seen that the role of price (demand) is more important in the market model, at least in the ex-vessel market. Moreover, in a market where supply is predetermined at a given time 't', it is the variable 'P' (price) that is required to be determined. The quantities can at best be assumed to be determined recursively, i.e., supply is determined by past prices (Tomek and Robinson 1981). Keeping this in view, the interest in the following sections will be to specify the demand equations for econometric estimation.

MARKET DEMAND EQUATIONS

In our demand model price is the logical dependent variable, while quantity of fish as well as prices and/or quantities of other substitute goods are specified as independent variables. There are other independent variables that will also be used in the model as important explanatory variables in estimating demand equations for different market levels. Moreover, since one of the objectives of the model building is to simulate price movements, it is quite logical to treat prices as a dependent variable (Waugh 1964; Tomek and Robinson 1981). Two recent studies by Wang et al. (1986) and Cook and Copes (1987) followed similar specifications, consistent with previously cited fishery economic models, e.g., Farrell and Lampe (1965), Waugh and Norton (1969), Bockstael (1977) and DeVoretz (1982).

AGGREGATION OF SUBMARKETS

Some of the submarkets at various market levels, defined earlier, can be aggregated into a single market with regard to the formulation of empirical function expressing the demand equations at various market levels. Such aggregation has been applied over space, species of fish and time.

Spatial aggregation. The specification of demand function for ex-vessel market within the space of the region will bring all scattered local markets and landing centers within one region under the influence of the same market forces and other exogenous factors. Such simplification is logical considering the fact that ex-vessel prices generated at the landing markets are based upon the flow of information and competition among buyers and sellers in regional, ex-vessel, and wholesale markets. The Padma-Meghna and Brahmaputra river system divides the whole country into four separate geographic regions. These four regions are quite distinct in terms of availability of fisheries resources, means of transport and communications. On this basis, therefore, we aggregated the small and segregated markets into four regional markets comprising the regions defined as SE (southeast), SW (southwest), NE (northeast) and NW (northwest) parts of the country. In the empirical models three instead of four regions have been distinguished by combining the southeast (SE) and northeast (NE) regions into a single region. However, at the retail level the aggregation will be broadened to reduce the regions into a single retail market.

Species aggregation. There are many varieties of species of fish captured from the rivers. However, not all of them are important in terms of ability to form a separate market. In fact, a great many of them are similar biologically and ecologically and/or have similar preference among buyers in terms of price and tastes.

The model considers six separate species markets, one each for four major species, i.e., hilsa, carp, catfish and prawn. The fifth market includes the remaining categories of fish (miscellaneous fishes) harvested from the open waters. The sixth market is considered for large prawns, since a sizeable quantity of large prawns are exported.

Temporal aggregation. Given the pattern of periodicity in the catch rates of different species of fish, two distinct seasonal markets (wet and dry season) have been distinguished for each species, which are quite consistent with the fishing calendar followed by small-scale riverine fishing. Based on the above, the monthly markets have been aggregated into two different seasonal markets. The months covered under each season are: April-September for the wet season and October-March for the dry season.

FUNCTIONAL FORM AND CHOICE OF VARIABLES

In selecting the functional form, simplicity was considered as one of the important criteria, although care was exercised to conform to the criteria of mathematical properties of functions and statistical tests. We defined the demand functions at various levels in terms of equations (45) to (47).

Ex-vessel Demand:
$$Pv_{ilmt} = f(Qv_{ilmt}, Pv_{xlmt}, P_{wilmt}, S_i) \quad ...45)$$

Wholesale Demand:
$$Pw_{ilmt} = g(Qw_{ilmt}, Pw_{xlmt}, Pr_{ilmt}, S_i) \quad ...46)$$

Retail Demand:
$$Pr_{imt} = h(Qr_{imt}, Pr_{xmt}, Np_t, In_t, S_i) \quad ...47)$$

where
- i = species (1, 2, ..., 5)
- l = region (1, 2, 3)
- m = season (1, 2)
- t = month/year
- Pv_i = ex-vessel price of species (i)
- Pw_i = wholesale price of species (i)
- Pr_i = retail price of species (i)
- Qv_i = landed quantity of species (i)
- Qw_i = net wholesale quantity traded in the region
  = $Qv_i + M_i - F_i$
  = landed quantity + regional import - regional export
- Qr_i = retail quantity of species (i)
- Pv_x = ex-vessel price of other species
- Pw_x = wholesale price of other species
- Pr_i = retail price of other species or substitute products
- Pv_i = ex-vessel price of species (i)
- Pw_i = price of species (i) in the wholesale market
- Pr_i = price of species (i) in the retail market
- Np = populaton size
- In = personal income
- S_i = size of fish caught.

Price Differences Between Market Levels and Postharvest Cost

A relationship between demand functions at various market levels (equations (45) to (47)) can now be established in terms of marketing margins, defined as the difference between primary and derived demand curves for a particular fish/fish products (Tomek and Robinson 1981). In such a case, retail demand function representing the primary demand is determined by the response of the ultimate consumer, while the ex-vessel and wholesale demand functions are derived demand functions determined by the price quantity relationship which exists at the ex-vessel level or an intermediate point where fish is purchased by wholesalers or processors. Thus, given several simplifying assumptions, the derived demand for fish at the ex-vessel and/or wholesale levels is obtained by subtracting the per unit costs (prices) of all the marketing and processing components from the primary demand functions. Fig. 3.8 shows demand curves at two market levels (ex-vessel and retail), assuming a perfectly elastic supply functions for marketing services (Tomek and Robinson 1981).

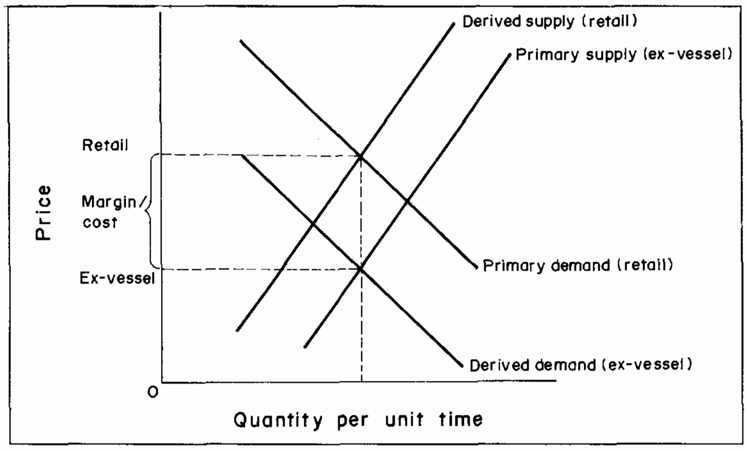


Fig. 3.8. Relationships between market levels in terms of marketing margins of fish output.

By a similar analogy the concepts of primary and derived supply can also be established. Primary supply refers to the relationship at the ex-vessel level. By adding an appropriate margin supply relations at other levels (e.g., retail) can be derived. A retail price is established at the point where primary demand and derived supply intersect (Fig. 3.8). Ex-vessel price is based on derived demand and primary supply. The difference between two prices can be treated as the marketing margin or cost of postharvest handling (processing, transporting and marketing)*. This concept was utilized to derive postharvest cost functions specified in the postharvest block of programming model.

*This analysis is based on the assumption of a competitive market structure where price is considered as the integrating force between market levels. For an illustration on this concept see Tomek and Robinson (1981).

CHAPTER 4
PARAMETER ESTIMATION: BIOECONOMIC AND MARKET SUBMODELS

Bioeconomic Submodel

Production and Cost Equations

Since the programming model is cast in a long-run framework, the cost coefficients must be derived from a long-run production function. Unfortunately, precise estimates for a long-run production function (yield function) are impossible at this stage as time series of catch and effort on each of these fisheries (either separate or in aggregate) are not available. Instead, a short-run relationship of yield and effort [equation (36)] was used, and subsequently the relationship of cost and yield shown in equation (37) was established for the current level of population through modelling individual fishing enterprises for each of the five species of fish mentioned earlier.

Also, the models for each species were separated by season (two seasons) and river groups (four groups). While separate equations were estimated for individual species in each season, dummy variables were used to capture structural differences in cost and production between the enterprises operating in different river groups. Equation (48) shows the structure of the cost function finally chosen for econometric estimation.

$$ACq_{il} = C(Q_{il}, D_k) \qquad \textbf{...48)}$$

where

i = species (1,2,..,5);

l = season (1,2);

Q = quantity of catch in weight;

D_k = dummy variables for river groups (D_1,D_2,D_3).

Given the short-run yield and cost curves for a given population size, the movement of the fishery with varying population sizes could be traced with the help of catchability coefficients, defined as the fraction of total stock removed by each unit of effort, assumed to be constant for each level of population size in the different fisheries. In such a case, a catchability coefficient for a fishery at any given level of population size will be proportional to the CPUE.

In determining such coefficients the relative fish population/stock size in different fisheries at current times in terms of density or current catch levels can be used. The values of current catchability coefficients in different fisheries will indicate the relative status of each fishery and the movement of long-run yield and cost functions as the population/stock size moves towards low to high or vice versa.

The movement of production traced through the procedure described above may not yield the true function through which each individual long-run production would move. However, in a sectoral framework, where effort allocation among fisheries follows interdependencies, identification of relative positions will suffice the need of the true function for analysis of policies and management issues.

Data

Data were obtained from a cross-sectional survey of fishing units operating in the rivers. The samples include fishing units operating in the three main river systems (Meghna, Padma and Jamuna-Brahmaputra) and three small rivers representing other river groups in the present modelling framework. In selecting the sample we used the Fisheries Department's survey of fishing village and fishing boats as the main reference (DOF/BFRSS 1982). The number of fishing boats recorded in this survey was roughly proportional to the estimated number of fishing units operating in different rivers (Table 34 - Appendix A). Based on the fishing village and fishing boat survey information, 12 areas in nine different districts covering the four river groups (Table 35 - Appendix A) were identified. The district(s) chosen for each river group were those constituting the largest fraction of total area under the river group (Table 33 - Appendix A).

The survey areas were selected on the criterion of large concentrations of fishing households to minimize cost and time and to obtain adequate samples from each area. A total of 415 samples were randomly selected (Table 35 - Appendix A) from among the list of fishers/fishing units available with the local fisheries officers (in most cases only a partial list was available).

The sampling design (Table 36 - Appendix A) showed only the distribution of fishing units by river group and season. Selection of sample fishing units by target species was not possible due to a lack of information in the sampling frame on the target species of the fishing unit. Data on input-output and costs were obtained for each fishing season by administering a structured questionnaire (Appendix B). The period covered was the 1987-88 fishing year (April-March) separated into the two seasons - wet season (April - September) and dry season (October - March).

Some important procedures followed in obtaining the data are as follows: input-output and cost data were obtained on a daily basis since the fishers customarily keep records and/or recall expenses for their day's fishing operation. Seasonal figures were obtained through multiplying by the total number of fishing days per season. In calculating the effort and cost per unit of effort only output of the direct (target) species group was considered. Catches of other species were considered incidental and treated as by-catch that augments income from fishing.

The raw data were processed using the statistical package SPSSPC+.

Estimation and Results

The estimation of regression equations followed the usual ordinary least squares (OLS). A linear functional form was fitted for equation (48). However, the dependent variable ACq was first computed using the formula in equation (38) before applying the OLS.

Although in each season models for each species in each river group were treated as separate, while performing the estimation a single regression was performed for all river groups, keeping only seasonal models separate (see specifications in equation (48)). However, dummy variables were used to distinguish one river group from the others in terms of production and cost structure in the cases of hilsa, carp, catfish and miscellaneous fish. For prawn, a single regression was performed combining datasets of all four river groups and two seasons. Two sets of dummy variables were used to represent differences due to season and river groups. This was done to have a larger sample size and thereby gain more degrees of freedom.

Table 4.1 shows the estimated average cost (ACq) equations for different species of fish in the rivers. As seen in Table 4.1, the 'F' values of AC equations for all the fisheries are significant. For hilsa and miscellaneous species fisheries, for instance, the

Table 4.1. Regression of average cost for a fishing unit in different riverine fisheries of Bangladesh.

Hilsa											
wet season (n = 210)											
AC =	8.78	+	0.00086Q	-	1.60D1	-	3.71D2	+	22.07D3		
	(0.61)		(4.74)***		(-1.55)		(-0.31)		(3.49)***		
R sq. = 0.27, R* sq. = 0.25, F = 13.28***											
dry season (n = 125)											
AC =	3.14	+	0.00056Q	+	11.01D1	+	15.73D2	+	21.91D3		
	(8.05)***		(4.70)***		(1.40)		(1.81)*		(1.65)*		
R sq. = 0.32, R* sq. = 0.29, F = 10.89***											
Carp											
wet season (n = 50)											
AC =	16.2	+	0.00075Q	+	11.8D1	+	2.23D2	-	4.76D3		
	(1.021)		(1.68)*		(1.85)*		(1.31)		(-1.5)		
R sq. = 0.42, R* sq. = 0.38, F = 5.5***											
dry season (n = 80)											
AC =	28.20	+	0.00041Q	-	10.54D1	-	5.77D2	-	22.32D3		
	(2.51)***		(4.06)***		(-1.90)*		(-1.71)*		(2.25)*		
R sq. = 0.63, R* sq. = 0.56, F = 8.49***											
Catfish											
wet season (n = 62)											
AC =	8.91	+	0.00027Q	-	17.64D1	+	19.45D2	+	20.07D3		
	(7.25)***		(1.78)*		(-.85)		(2.31)*		(1.72)		
R sq. = 0.64, R* sq. = 0.52, F = 5.29***											
dry season (n = 87)											
AC =	10.91	+	0.029Q	+	3.38D1	+	19.45D2	+	12.83D3		
	(1.45)		(4.17)***		(0.92)		(1.66)*		(1.88)*		
R sq. = 0.32, R* sq. = 0.28, F = 4.72***											
Prawn											
all season (n = 45)											
AC =	26.36	+	0.034Q	+	34.38D1	+	39.97D2	-	19.98D3	+	4S
	(5.47)***		(1.93)*		(1.72)		(1.86)*		(-0.88)		(1.67)
R sq. = 0.58, R* sq. = 0.45, F = 4.38***											
Miscellaneous											
wet season (n = 68)											
AC =	2.62	+	0.00175Q	+	14.07D1	+	7.01D2	+	2.66D3		
	(10.92)***		(9.06)***		(2.26)**		(1.84)*		(1.93)*		
R sq. = 0.64, R* sq. = 0.52, F = 5.29***											
dry season (n = 93)											
AC =	2.83	+	0.0126Q	+	9.95D1	+	6.42D2	+	3.95D3		
	(0.82)		(2.20)***		(2.30)**		(1.26)		(0.88)		
R sq. = 0.29, R* sq. = 0.26, F = 3.72***											

Notes:
AC = average cost of catch;
Q = total catch;
Di = dummy variables for rivers (i = 1, 2, 3); (D1 = 1 for River 1 and 0 otherwise); (D2 = 1 for River 2 and 0 otherwise); (D3 = 1 for River 3 and 0 otherwise);
S = seasonal dummy variable; (S = 1 for dry season and 0 for wet season);

* significant at 10%
** significant at 5%
*** significant at 1%

F values are significant at 1% in both dry and wet seasons. Similarly, the 't' values (two-sided) for the output coefficients in the AC equations are significant for all fisheries. In the case of dummy variables representing different rivers and seasons (in the case of prawn), most of them are significant. The (adjusted) R^2 are, however, lower than 0.50 in most cases. The lowest R^2 is observed for the miscellaneous species fishery in the dry season (0.26).

The AC equations for each fishery in Table 4.1 can be separated by river groups and seasons. Table 4.2 shows AC equations for the hilsa fishery separated by river groups in each season. The AC equations for other fisheries are shown in Table 37 - Appendix A.

Again, assuming that the cost parameters for the micro firms correspond to those for the entire fishery, the aggregate AC functions can be derived from the micro functions shown in Table 4.2 and Table 37 - Appendix A. The aggregate AC equations for each species separated by river group in each season are shown in Table 38 - Appendix A. Notice that the intercepts of the aggregate AC equations are the same as those of the corresponding sample AC equations, while only the slopes are different. In deriving the slope of the aggregate AC equations the aggregate average catch per season for the entire fishery has been substituted into the sample AC equation at the average catch rate for the sample, using the formula given below:

$$C^* = c^* \times q\sim / Q\sim \qquad \ldots 49)$$

where

C^* = slope of aggregate AC equation;
c^* = slope of sample AC equation;
$q\sim$ = average catch rate for the sample;
$Q\sim$ = average catch rate for the fishery.

The aggregate AC functions for hilsa fishery are shown in Table 4.3.

Table 4.2. Computed average cost equations for a hilsa fishing unit in various seasons in the riverine fisheries of Bangladesh.

River group	Equations
River 1	
-dry season	AC = 11.62 + 0.00056q
-wet season	AC = 7.185+ 0.00086q
River 2	
-dry season	AC = 18.87 + 0.00056q
-wet season	AC = 5.075+ 0.00086q
River 3	
-dry season	AC = 25.05 + 0.00056q
-wet season	AC = 30.85 + 0.00086q
River 4	
-dry season	AC = 3.14 + 0.00056q
-wet season	AC = 8.78 + 0.00086q

Source: Based on estimated regression equations for sample fishing units.
Notes:
AC = average cost (BDT);
q = catch (kg).

Table 4.3. Aggregate average cost equations for hilsa fishery in various seasons in the riverine fisheries of Bangladesh.

River group	Aggregate AC equations
River 1	
-dry season	AC = 11.62 + 0.000289Q
-wet season	AC = 7.185+ 0.00021Q
River 2	
-dry season	AC = 18.87 + 0.00285Q
-wet season	AC = 5.075+ 0.00312Q
River 3	
-dry season	AC = 25.05 + 0.00225Q
-wet season	AC = 30.85 + 0.0035Q
River 4	
-dry season	AC = 3.14 + 0.00057Q
-wet season	AC = 8.78 + 0.00029Q

Source: Computed at the average rate of catch per season and based on equations in Table 4.2.
Notes:
AC = average cost (BDT);
Q = catch ('000 kg).

Market Submodel

Market Demand Equations and Data

In estimating the market demand models with the use of the specified choices of variables in equations (45) to (47) an initial problem of data availability was encountered. First the complete absence of series and wholesale prices of different species of fish led to the dropping of the wholesale demand function from estimation. Price-quantity data on ex-vessel and retail levels were available only as monthly series for the period covering July 1983 - September 1987 mainly from published and unpublished records of the Bangladesh Fisheries Resource Survey System (BFRSS) in the Department of Fisheries and the published Monthly Statistical Bulletin of Bangladesh Bureau of Statistics (BBS 1984, 1985, 1986). The Department of Fisheries has available districtwise monthly records of ex-vessel landed quantities of fish from rivers by major species and their values. The Bangladesh Bureau of Statistics publishes monthly retail prices of important species of fish in selected districts. Monthly estimates of both ex-vessel and retail demand models were made based on districts.

With the time-frame of demand estimates being reduced to months, the use of size of population as a possible explanatory variable became less important, while the personal income data by month were unavailable from published statistical sources.

Since prices are nominal prices they have been deflated by the index of monthly consumer food price index (CPI) in the absence of an index of inflation. In a similar manner, catch quantities have been deseasonalized using a seasonal index in estimating retail demand equations.

Considering the data limitations and the above qualifications, retail and ex-vessel demand models were estimated for the six species groups.

For retail demand, a single market was assumed for each species (equation (50)). The variable list includes price of the species to be modelled as the dependent variable and its quantity and prices of all other groups as well as prices of chicken and beef as independent variables. The provision for a structurally different market between wet and dry seasons has been kept in the model through the inclusion of a dummy variable as one of the explanatory variables. In the case of big prawn the prices depend exogenously on the international market price. As such, their domestic retail price has been assumed to correspond to the export price and hence dropped from estimation in terms of a structural equation.

Significant structural differences over geographic regions and fishing seasons were explicitly considered in the case of the ex-vessel market [equation (51)]. Three regions (A, B and C) were defined for the ex-vessel market for each species. Catch quantities in Region A include the harvest from other rivers in the southeast and northeast Bangladesh and the Upper Meghna River; in Region B harvests include those from the lower Meghna River, Lower Padma River and other rivers in the southwestern part of Bangladesh; and in Region C they include the harvest from the Upper Padma River, Jamuna-Brahmaputra River and other rivers in northwestern Bangladesh. While separate functions were estimated for each region, seasonal differences in the price relations were explained with the help of a dummy variable. However, in the case of large prawns, only one ex-vessel market was assumed.

In the ex-vessel market model for a species in a particular region the variables included as explanatory variables were the region's ex-vessel quantity of the modelled species groups, ex-vessel prices of other groups in the region, ex-vessel prices of the various species groups in other regions, and retail prices of other species groups and other products. To model ex-vessel market for large prawns, their export price in the international market was considered most important in addition to its ex-vessel price. However, in the absence of a time series on export price, FOB (freight on board) values of prawn and shrimp were used as a proxy variable.

Retail market: $P_i = F(Q_i, P\sim_i)$ ...50)

Ex-vessel market: $P^x_{ij} = G(Q^x_{ij}, P^x\sim_{ij}, P^{x*}_{jk}, P_i, D)$ ...51)

where

P_i = retail prices of fish and other animal proteins;
Q_i = retail quantity of i^{th} species;
$P\sim_i$ = retail prices of cross products (fish and other animal protein;
P^x = ex-vessel price of i^{th} species in j^{th} region;
Q^x = ex-vessel quantity of i^{th} species in the j^{th} region;
$P^x\sim$ = ex-vessel prices of other species in j^{th} region;
P_{x*} = ex-vessel prices of all species in other regions;
D = dummy variable;
= 1 for dry months: October-March
= 0 for wet months: April-September
i = fish and animal protein (1, 2, .., 8)
1 = hilsa, 2 = carp, 3 = catfish, 4 = small prawns, 5 = miscellaneous fish, 6 = beef, 7 = chicken, 8 = large prawns
j = region (1, 2, 3)
1 = Region A, 2 = Region B, 3 = Region C.

Data Evaluation

The statistical characteristics of the raw data and their transformed version may give rise to some potential biases and distortions open for questions and challenges. Some of the transformations and the potential biases in the data are discussed below:

First, the retail quantity data were the monthly amount produced - not consumed. Inventory adjustments, reductions due to postharvest processing and spoilage of production during postharvest handling in the course of marketing in the final retail market were not considered to correct for any difference in production and consumption. However, the resulting biases would still be considered minimum given the fact that most of the fishes harvested from the riverine environment are consumed fresh without much processing and product transformations.

Second, the quantity measures for each species were not ideal. They assume homogeneity within each fish species since quantity is defined in tonnes. Clearly, different sizes of fish that led to price differentials were not captured in the ex-vessel quantity and its value. Gates (1974) and DeVoretz (1982) cast serious doubt on such measures of quantity, and the former (Gates) opines that the same levels of landings in weight terms are associated with two equilibrium prices: one price for large fish and a lower price for small fish.

Third, the choice of substitute price for each species was arbitrary in the absence of a predetermined criterion. However, with respect to other substitute fish an arbitrary choice will not result in significant bias since consumers are largely indifferent in their preference and choice of fish. But the same may not be true with respect to choice between beef and poultry as substitute for each species. Fortunately, the price of beef has a direct bearing with imported livestock through informal trade in addition to domestic beef production. This phenomenon might have introduced a bias in the price of beef and hence its inclusion as an explanatory variable might give less useful results. Considering this fact, and the presence of a high correlation between the beef price and poultry price we used poultry price as one of the explanatory variables in the final specification of retail demand models that were used for estimation.

Fourth, all prices, retail as well as ex-vessel, were deflated by the CPI. The biases resulting from such computation are also expected to be minimal.

Finally, the absence of an income variable in the model will introduce a bias in the estimates of flexibility (elasticity) coefficients for both own and cross prices, and, therefore, make the model less powerful for price (demand) forecasts.

Since the models are multivariate in nature they were a significant source of multicollinearity, one of the frequently encountered problems in econometric estimation of statistical models with multiple explanatory variables. Under this circumstance only a few among the listed variables in equations (50) and (51) were used in the final estimation keeping in mind the goodness of fit, level of significance of the model and its parameter estimates including the signs in each case. The rest of the variables were dropped from the specification of the models.

Similarly, the seasonal dummy variable 'D' was also dropped from the specifications of those models where it appeared least important and/or became an additional source of multi-collinearity as well as distortion of expected signs, and a loss of goodness of fit and significance of the key variable (quantity) and the model itself.

Estimation and Results

The model has been cast as a single equation price dependent and supply independent. Therefore, the OLS method was chosen to fit a natural linear functional form and estimated. The natural linear functional form was estimated consistent with the main objective of its formulation, i.e., to provide an appropriate price mechanism in the programming model that can handle only linear demand specifications. The use of single equation model with OLS technique was found to be more practical in a number of instances and hence, it has been used and advocated by some authors, e.g., Labys (1973), Wang (1976), DeVoretz (1982), Wang et al. (1986) and Cook and Copes (1987).

It should be mentioned here that DeVoretz (1982) made a comparison between the parameter estimates of single equation price-dependent models and those of single equation quantity dependent and simultaneous equation models. His findings show that price dependent models are superior to their counterpart (quantity-dependent models). Also, between the OLS estimates of a price-dependent model and two SLS (two stage least square) estimates of simultaneous equation model, the former was found to yield best fit with little associated time series problems, whereas the latter yielded poor overall fit with some variables with either wrong sign or being insignificant.

The problem of autocorrelation and moving average errors also became significant for certain specifications. Under such circumstances attempts were made to correct them through a respecification. However, since such problems became unavoidable the familiar Box-Jenkin technique or ARIMA was applied to overcome the problem.

The empirical results of the market models for each species at both retail and ex-vessel level are presented in Tables 4.4 and 4.5, respectively. As shown in Table 4.4, in the case of retail demand the specifications have high explanatory power and are free from autocorrelation. The adjusted R^2 ranges between 0.70 in the case of hilsa and 0.91 in the case of carp. The D-W are significant at 5% for all cases. The F values are significant at 1% level of significance. The coefficients of the explanatory

Table 4.4. Estimates of monthly retail demand models for various species harvested from the rivers of Bangladesh.

Species	Equation				R^2	D-W	F value
Hilsa	P1 = 4.52	- 0.0002Q1	+ 0.89P5	+ 0.16P7	0.70	1.96	23.69
(n=50)	(-0.79)	(-2.54)***	(3.28)***	(0.63)			
Carp	P2 = 21.71	- 0.0068Q2	+ 0.84P5	+ 0.19P7	0.91	2.06	118.90
(n=50)	(6.44)***	(-7.68)***	(5.74)***	(1.38)			
Catfish	P3 = -0.71	- 0.0003Q3	+ 0.41P5	+ 0.19P7	0.84	1.94	50.90
(n=50)	(-0.21)	(3.12)***	(2.50)***	(3.29)***			
Small prawns	P4 = 0.90	- 0.0013Q4	+ 0.47P5	+ 0.52P7	0.88	2.24	91.37
(n=50)	(0.10)	(-2.41)**	(2.46)***	(2.14)**			
Miscellaneous fish	P5 = 3.72	- 0.0001Q5	+ 0.2P1	+ 0.54P7	0.90	1.98	86.26
(n=50)	(1.13)	(-0.79)	(3.47)***	(5.67)***			

Notes:
Pi = retail price per kg of species;
Qi = quantity sold in thousand kg;
i = 1,2,3,4,5,7 where 1 = hilsa, 2 = carp, 3 = catfish, 4 = small prawns, 5 = miscellaneous fish and 7 = poultry.
* significant at 10%.
** significant at 5%.
*** significant at 1%.

Table 4.5. Estimates of monthly ex-vessel demand models for various species harvested from the rivers of Bangladesh.

Species	Equation						R^2	D-W	F
Hilsa									
P1.1 = 1.80	- 0.0017Q1.1	+ 0.54P1.2	+ 0.31P5	+ 2.25D1			0.53	2.56	10.2
(0.25)	(-1.24)	(3.47)***	(1.30)	(1.32)					
P1.2 = -1.10	-0.00019Q1.2	+ 0.41P1.1					0.71	1.97	14.33
(-2.8)	(-2.35)**	(3.71)***							
+0.34P1.3	+ 0.12P1	+ 0.032P3.2	+ 0.46P5.2						
(1.96)*	(0.86)	(0.33)	(0.26)						
P1.3 = 5.63	- 0.0024Q1.3	= 0.36P1.2	+ 0.049P5	+ 0.30P1			0.50	2.01	7.24
(0.89)	(-0.78)	(2.42)**	(0.20)	(1.69)					
Carp									
P2.1 = 29.9	- 0.0064Q2.1	+ 0.09P2.2	+ 0.14P3.1	- 3.76D			0.55	2.05	7.19
(6.89)***	(-2.48)***	(0.79)	(0.96)	(2.75)***					
P2.2 = -7.15	- 0.024Q2.1	+ 0.23P2.3	+ 0.55P2	+0.12P4.2			0.56	1.79	8.87
(0.54)	(-1.12)	(2.26)**	(2.24)**	(0.69)					
P2.3 = 5.33	- 0.04Q2.3	+ 0.24P2.1	+ 0.54P2.2	+0.27P4.3			0.49	1.95	5.97
(0.59)	(2.28)**	(2.04)**	(3.83)***	(2.17)**					
Catfish									
P3.1 = -0.73	- 0.0027Q3.1	+ 0.21P3.3	+ 0.25P5	+0.15P4.3	+	0.19P4	0.49	2.35	7.18
(-0.13)	(-0.65)	(1.76)*	(1.38)	(1.86)*		(2.13)**			
P3.2 = 10.25	- 0.008Q3.2	+ 0.079P3.3	0.58P5.2	+ 4.64D1			0.59	1.98	9.81
(1.71)*	(-1.87)*	(0.44)	(2.84)***	(2.56)***					
P3.3 = 9.32	- 0.012Q3.3	+ 0.1P3.2	+ 0.25P5.3	+ 0.39P1			0.49	1.81	8.82
(2.49)	(-1.85)*	(1.00)	(1.41)	(3.00)***					
Small prawns									
P4.1 = 16.97	- 0.0042Q4.1	+ 0.12P4.2	+ 0.21P1	+ 2.54D1			0.55	1.98	7.41
(1.53)	(-2.39)**	(1.13)	(0.76)	(1.08)					
P4.2 = 4.68	- 0.0069Q4.2	+ 0.18P4.1	+ 0.35P2				0.53	1.96	7.99
(0.67)	(-4.45)***	(1.66)*	(2.93)***						
P4.3 = -14.85	- 0.097Q4.3	+ 0.1P4.2	+ 0.74P2	+ 0.16P1			0.49	2.11	8.72
(-1.70)*	(-2.69)***	(0.49)	(3.75)***	(0.83)					

continued

Table 4.5 continued

Species	Equation	R^2	D-W	F
Miscellaneous fish				
P5.1 =	13.15 - 0.0019Q5.1 + 0.2P5 + 0.11P1	0.53	1.98	7.96
	(2.45)*** (-4.21)*** (1.10) (1.55)			
P5.2 =	-3.91 - 0.001Q5.2 + 0.49P5 + 0.47P1.2 - 2.12D1	0.56	1.97	18.33
	(-0.55) (-2.09)** (2.11)*** (3.38)*** (-1.59)			
P5.3 =	1.91 - 0.0037Q5.3 + 0.63P5 +0.037P3.3	0.62	1.93	10.93
	(0.25) (-2.87)*** (2.72)*** (0.35)			
Large prawns				
P8.0 =	106.00 - 0.037Q8.0 +0.00006FOB + 1.04P4	0.68	1.89	12.09
	(3.33)*** (-4.40)*** (1.74)** (1.11)			

Notes:
*** significant at 1%
** significant at 5%
* significant at 10%
Pi = retail price/kg;
Pi.j = ex-vessel price/kg;
Q = quantity sold in thousand kg;
i = 1, 2, ..., 8 where (1 = hilsa, 2 = carp, 3 = catfish, 4 = small prawns, 5 = miscellaneous fish, 6 = beef, 7 = poultry, 8 = large prawns);
j = 0, 1, 2, 3 where (0 = all region, 1 = region A, 2 = region B and 3 = region C); and
FOB = export value of large prawns and shrimp.

Table 4.6. Price flexibility coefficients for retail demand parameters of various riverine species in Bangladesh.

Species	Own price	Cross prices			
		Hilsa	Carp	Misc.	Poultry
Hilsa	0.06			1.00	0.24
Carp	0.08			0.49	0.15
Catfish	0.007			0.39	0.64
Small prawns	0.05		0.49		0.42
Miscellaneous fish	0.02	0.18			0.71

variables have correct signs, i.e., negative for its own quantity and positive for all substitute prices, and most of the parameter estimates are significant.

As for the ex-vessel demands (Table 4.5) the explanatory powers are, in general, poorer than their counterparts of the retail market, the R^2 values being in the range of 0.49 and 0.71. However, the models themselves and most of the parameters are significant, with proper signs. The D-W values are also significant at the 5% level of significance.

The economic parameters e.g., price flexibilty coefficients have biased implications for the markets for various species of fish and their production in the absence of an income variable in the present models. Nevertheless, these measures are a useful indicator of relative movements in the sales revenue of both retailers and producers (fishers) of different species groups of fish in different regions of the country. The

Table 4.7. Price flexibility coefficients for ex-vessel demand parameters of various riverine species in Bangladesh.

Species	Own price		
	Dry season	Wet season	All season
Hilsa			
- Region A	0.0037	0.05	
- Region B			0.07
- Region C			0.02
Carp			
- Region A	0.03	0.02	
- Region B			0.02
- Region C			0.08
Catfish			
- Region A			0.03
- Region B	0.03	0.04	
- Region C			0.06
Small prawns			
- Region A	0.04	0.1	
- Region B			0.16
- Region C			0.13
Miscellaneous fish			
- Region A			0.36
- Region B	0.05	0.05	
- Region C			0.14
Large prawns			0.09

values of such parameters generated at the mean values of the sample data are summarized in Tables 4.6 and 4.7.

The demand for all the fish species is highly price inflexible in all markets for all species of fish (Tables 4.6 and 4.7). This implies that if there has been an increase in the supply, for instance through better management, there will be an increase in the sales revenue in both markets (retail and ex-vessel).

However, the degree of inflexibility differs among individual species as well as from market to market and region to region. This implies that there will be a differential effect on the sales revenue of the traders depending on the market level, species type and regions of fish production and trade, for a given change in the supply. For instance, in the retail market the positive revenue impact of an increased supply will be the largest for catfish (the price flexibility coefficient being the lowest at 0.007) and smallest for carp (the price flexibility coefficient being the highest at 0.08). Similarly, in the ex-vessel market such impact will be highest for the dry-season hilsa market in Region A and lowest for miscellaneous fish market in Region A (see Table 4.7).

Although in general ex-vessel prices are expected to be more flexible than the retail prices, the coefficients of price flexibility at the ex-vessel market of certain fish in certain regions are lower than that of the corresponding retail market.

In Tables 4.8 and 4.9 the retail and ex-vessel demand functions have been reduced to equations in terms of their own quantities. Since price of substitutes acted as shift variables in the demand models their average values were incorporated to compute the equations in Tables 4.8 and 4.9. These equations were used as functional parameters

Table 4.8. Monthly retail demand equations for various species landed from rivers of Bangladesh.

Species	Equation	Mean value of sample variables (S.D.)			
Hilsa N = 50	P1 = 26.59 - 0.0002Q1	Q1 =7,572 (7,201)	P1 =25.30 (5.37)	P5 =28.14 (4.12)	P7 =37.90 (4.21)
Carp N = 50	P2 = 52.54 - 0.0068Q2	Q2 = 573 (410)	P2 =48.63 (6.70)	P5 =28.14 (4.12)	P7 =37.90 (4.21)
Catfish N = 50	P3 = 29.39 - 0.0003Q3	Q3 = 659 (376)	P3 =27.44 (4.80)	P5 =28.14 (4.12)	P7 =37.90 (4.21)
Small prawns N = 50	P4 = 49.47 - 0.0013Q4	Q4 =1,864 (869)	P4 =40.15 (9.06)	P2 =48.63 (6.70)	P7 =37.90 (4.21)
Miscellaneous fish N = 50	P5 = 29.25 - 0.0001Q5	Q5 =6,050 (1,815)	P5 =28.13 (4.12)	P1 =25.30 (5.37)	P7 =37.90 (4.21)

Source: Computed at the mean value of the sample shift variables.
Notes:
Pi = retail price (i = 1, 2, 3, 4, 5, 7) of hilsa, carp, catfish, small prawns, miscellaneous fish and poultry, respectively.
Qi = retail quantity (i = 1, 2,..., 5) of hilsa, carp, catfish, small prawns and miscellaneous fish, respectively.

Table 4.9. Monthly ex-vessel demand equations for various species harvested from the rivers of Bangladesh.

Species Equations	Mean value of sample variables (S.D.)		
Hilsa			
P1.1 = 20.86 -0.0017Q1.1 + 2.25D	Q1.1 =649 (688)	P1.1 = 20.89 (4.83)	
N=33	P1.2 = 18.26 (3.24)	P5 =30.17 (4.50)	
P1.2 = 19.61 -0.00019Q1.2	Q1.2 =6,759 (6,634)	P1.2 = 18.26 (4.57)	
N=32	P1.1 = 20.89 (4.83)	P1.3 = 21.70 (3.80)	P1 = 27.11 (4.72)
	P3.2 = 22.71 (5.52)	P5.2 = 17.15 (4.02)	
P1.3 = 21.85 -0.0024Q1.3	Q1.3 =147 (170)	P1.3 = 21.70 (3.80)	
N=32	P1.2 = 18.26 (4.50)	P5 = 30.17 (3.24)	P1 = 27.11 (4.72)
Carp			
P2.1 = 35.86 -0.0064Q2.1 - 3.76D	Q2.1 =277 (251)	P2.1 = 32.50 (3.87)	
N=32	P2.2 = 33.09 (6.16)	P3.1 = 20.82 (3.43)	
P2.2 = 32.94 -0.024Q2.2	Q2.2 = 26 (43)	P2.2 = 33.09 (6.16)	
N=32	P2.3 = 35.97 (8.32)	P4.2 = 24.40 (5.03)	
P2.3 = 38.28 -0.04Q2.3	Q2.3 = 68	P2.3 = 35.97	
N=32	(57)	(8.32)	
	P2.1 = 32.50 (3.87)	P2.2 = 33.09 (6.16)	

continued

Table 4.9. (Continued)

Species	Equations		Mean value of sample variables (S.D.)		
Catfish					
P3.1 = 21.35	-0.0027Q3.1		Q3.1 =232	P3.1 = 20.67	
N=33			(153)	(3.48)	
			P3.3 = 25.83	P5.1 = 16.5	P4.3 = 26.7
			(4.02)	(2.77)	(6.67)
P3.2 = 22.22	-0.008Q3.2	+ 4.64D	Q3.2 =202	P3.2 = 22.73	
N=32			(222)	(5.61)	
			P3.3 = 25.86	P5.2 = 17.13	
			(4.09)	(4.08)	
P3.3 = 27.81	-0.012Q3.3		Q3.3 =120	P3.3 = 25.83	
N=33			(88)	(4.02)	
			P1.3 = 21.69	P2.3 = 35.97	P5.3 = 20.6
			(3.81)	(8.32)	(3.70)
Small prawns					
P4.1 = 30.93	-0.0042Q4.1	+ 2.54D	Q4.1 =955	P4.1 = 28.16	
N=32			(561)	(5.51)	
			P4.2 = 24.41	P2 = 52.52	
			(5.02)	(4.85)	
P4.2 = 28.13	-0.0069Q4.2		Q4.2 =560	P4.2 = 24.41	
N=32			(413)	(5.02)	
			P4.1 = 28.16	P2 = 52.52	
			(5.51)	(4.85)	
P4.3 = 30.50	-0.097Q4.3		Q4.3 = 37	P4.3 = 26.73	
N=33			(24)	(6.67)	
			P4.2 = 24.33	P2 = 52.13	P1 = 27.1
			(4.96)	(5.27)	(4.71)
Miscellaneous fish					
P5.1 = 21.53	-0.0019Q5.1		Q5.1 =3,021	P5.1 = 16.33	
N=32			(801)	(4.12)	
			P5 =30.43	P1.1 = 20.88	
			(2.95)	(4.91)	
P5.2 = 19.62	-0.001Q5.2	+ 2.12D	Q5.2 =1,685	P5.2 = 17.13	
N=32			(1,050)	(4.08)	
			P5 =30.43	P1.2 = 18.33	
			(2.95)	(4.62)	
P5.3 = 22.03	-0.0037Q5.3		Q5.3 =717	P5.3 = 20.83	
N=32			(445)	(3.51)	
			P5 =30.43	P3.3 = 25.86	
			(2.95)	(4.09)	
Large prawns					
P8.0 =151	-0.037Q8.0		Q8.0 =374	P8.0 =137.5	
N=27			(417)	(25.59)	
			FOB =146,527	P4 = 35.13	
			(109,634)	(4.5)	

Source: Computed at the mean value of the sample shift variables.

Notes:

D = seasonal dummy variable (= 1 for dry season, = 0 otherwise).
Pi = retail price/kg;
Pi.j = ex-vessel price/kg;
Q = quantity sold in thousand kg;
i = 1, 2, ..., 8 where (1 = hilsa, 2 = carp, 3 = catfish, 4 = small prawns, 5 = miscellaneous fish, 6 = beef, 7 = poultry, 8 = large prawns);
j = 0, 1, 2, 3 where, (0 = all region, 1 = region A, 2 = region B and 3 = region C); and
FOB = export value of large prawns and shrimp.

in the programming model solved in Chapter 5. The retail demand equations in Table 4.8 yield the revenue and benefit functions of the programming model.

The difference between the retail price and ex-vessel price is treated as the margin of the fish trading sector (postharvest operators) from the point of ex-vessel trade to the retail sales. Under a perfectly competitive market this difference (margin) represents traders' (postharvest operators') nominal cost of transporting, handling, processing and marketing activities, and normal returns on trading capital as well as profits (payments) to their labor and enterpreneurial skills (Tomek and Robinson 1981). Therefore, the margins of the trading sector can be treated as the opportunity cost of postharvest handling, hence they constitute part of the social cost in the fisheries production process. Table 39 - Appendix A shows the equations of post-harvest cost (market margin) for different species produced from the rivers in different regions of the country, which have been derived as the difference between retail and ex-vessel prices shown in Tables 4.4 and 4.5, respectively.

Table 5.2. Distribution of catch (t) of various species and level of effort (gear hours x 10^6) in the Base Model for riverine fisheries of Bangladesh by river group.

Species	River 1 (Meghna)	River 2 (Padma)	River 3 (Jamuna-B.putra)	River 4 (Others)	Total
Hilsa					
Total catch	50,315	2,986	660	24,200	78,161
-direct catch	47,000	2,750	600	20,000	70,350
-by-catch	3,315	236	60	4,200	7,811
Total effort	76,050	5,095	1,756	28,420	111,321
Prawn					
Total catch	1,883	211	286	15,601	17,981
-direct catch	1,550	120	180	12,000	13,850
-by-catch	333	91	106	3,601	4,131
Total effort	3,600	346	168	12,690	16,804
Catfish					
Total catch	1,067	383	858	6,973	9,281
-direct catch	900	300	760	6,000	7,960
-by-catch	167	83	98	973	1,321
Total effort	1,425	494	1,367	6,050	9,336
Carp					
Total catch	872	120	573	5,548	7,113
-direct catch	700	60	481	4,500	5,741
-by-catch	172	60	92	1,048	1,372
Total effort	1,660	116	458	11,420	13,654
Miscellaneous fish					
Total catch	9,805	2,170	3,946	44,706	60,627
-direct catch	6,800	1,400	3,000	30,756	41,956
-by-catch	3,005	770	946	13,950	18,671
Total effort	11,058	1,586	2,935	30,360	45,939
All species					
Total catch	63,942	5,870	6,323	97,028	173,163
-direct catch	56,950	4,630	5,021	73,256	139,857
-by-catch	6,992	1,240	1,302	23,772	33,306
Total estimated effort	93,793	7,637	6,684	88,940	197,054
Total actual effort[a]	221,320	26,555	16,062	166,367	430,304
Total actual catch[b]	72,710	7,943	8,741	109,325	198,719

[a]Approximate levels based on sample survey by the author, and survey of fishing units by DOF (unpubl. data).
[b]Actual average annual catch during 1983-84 to 1986-87 (Source: DOF, unpubl. data).

Considering the year to year fluctuation of catch (Table 2.2), the model results (Table 5.2) can be considered as a reasonable approximation to the current exploitation intensity of the various species groups. Therefore, the structure of the Base Model can be used as a tool to simulate the behavior of the riverine fisheries of Bangladesh with respect to effort allocation, fish production and benefit generation to the society in an economically efficient manner.

In terms of fishing effort, the total amount of fish (173,163 t) per annum noted above requires 197,054 gear hours x 10^6 of fishing operations. Of these, hilsa alone

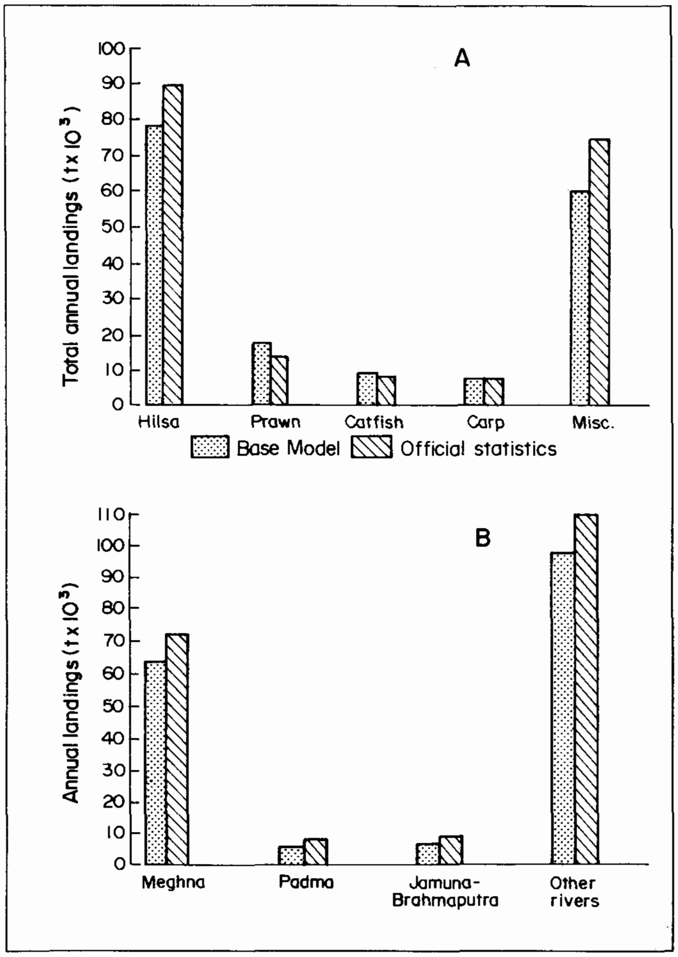


Fig. 5.1. Comparison of Base Model landings and official landings from the rivers of Bangladesh, 1983-84 to 1986-87. A. by species groups; B. by river groups.

requires 54% (Table 5.1). The aggregate CPUE (catch/gear hour x 10^6) is 879 kg. However, the CPUE expressed as the ratio of direct catch to total effort is the highest (895 kg/gear hour x 10^6) for the miscellaneous group fishery and lowest for carp (420 kg/gear hour x 10^6).

Again, as shown in Table 5.2 most of the effort is allocated in River 1 (Meghna) and River 4 (Other rivers) (48% and 45%, respectively). Thus, River 2 (Padma) and River 3 (Jamuna-Brahmaputra) employ only 7% of the total effort. River 4 (Other rivers) has the highest catch per unit of effort (1,091 kg/gear hour x 10^6).

Given the available statistics on the total number of fishing units (Table 34 - Appendix A) operating in the riverine fisheries of Bangladesh and based on the average size of fishing gear and amount of fishing time per fishing unit (Tables 46 and 47 - Appendix A), the current actual annual level of effort is roughly 430,304 gear hours x 10^6, which is about 118% higher than the level of effort shown by the result of the Base Model. Compared to the current average catch level of 198,000 t·year^{-1} the existing level of effort is, therefore, much in excess of what is economically desirable to produce the similar amount of catch.

As for individual rivers, shown in Table 5.2, the size of current effort is higher by 136% in River 1 (Meghna), 247% in River 2 (Padma), 140% in River 3 (Jamuna-Brahmaputra) and 87% in River 4 (Other rivers). This shows that the principal rivers, especially, the Padma River, have a relatively higher pressure of excess capacity than the Other rivers.

Table 5.3. Regional share of total landings and postharvest cost in the Base Model for riverine fisheries of Bangladesh.

Species	Reg. A (SE & NE)	Reg. B (SW)	Reg. C (NW)	Total
Hilsa				
-landings (t)	5,938	70,905	1,318	78,161
-postharvest cost[a]	24.88	480.74	4.66	510.28
-cost per landed kg (BDT)	4.19	6.78	3.54	6.53
Prawn (small)				
-landings (t)	8,900	6,004	387	15,291
-postharvest cost[a]	168.01	138.19	9.82	316.02
-cost per landed kg (BDT)	18.88	23.02	25.37	20.67
Prawn (large)				
-landings (t)				2,690
-postharvest cost[a]				81.98
-cost per landed kg (BDT)				30.48
Catfish				
-landings (t)	4,841	2,819	1,621	9,281
-postharvest cost[a]	42.91	14.23	4.95	62.09
-cost per landed kg (BDT)	8.86	5.05	3.05	6.69
Carp				
-landings (t)	5,710	503	900	7,113
-postharvest cost[a]	96.52	7.97	12.98	117.47
-cost per landed kg (BDT)	16.90	15.84	14.42	16.51
Miscellaneous fish				
-landings (t)	36,000	16,588	8,039	60,627
-postharvest cost[a]	459.4	193.99	74.46	727.85
-cost per landed kg (BDT)	12.76	11.69	9.26	12.01
Total				
-landings (t)	61,389	96,819	12,265	173,163[b]
-postharvest cost[a]	792.00	835.00	107.00	1,815.7[b]
-cost per landed kg (BDT)	12.90	8.62	8.72	10.01

[a]In million Bangladesh Taka (US$1 = BDT32).
[b]Figure shows column total only.

Total cost of harvest and postharvest activities is BDT4,083 million, which is 77% of the gross revenue. Again, of the total cost, 57% represents cost of fishing effort (harvest cost). The remaining 43% (BDT2,435 million) represents market margin or the cost of postharvest handling, processing and transporting of fish and fish products. Market margins vary widely among species groups. As shown in Table 5.1, postharvest cost (representing margins), is as high as 43% of retail price in the case of small prawns and as low as 19% of export price in the case of large prawns.

Moreover, the structure of postharvest cost is different in various regions of the country for each species group. Table 5.3 shows the distribution of catch by region and corresponding cost of postharvest handling and marketing. Region A presents the highest average postharvest cost (BDT13/kg) as compared to the other two regions (BDT9/kg).

The cost of postharvest handling has a distributive implication on the benefits generated in the fisheries production process. The value of postharvest cost margins (shown in Tables 5.1 and 5.3) has been defined as the actual input cost (transportation, ice, labor, packing materials, etc.), plus the opportunity cost of capital and managerial skill. In the actual conduct of postharvest activities the operators incur a relatively lesser cost in terms of actual input cost as compared to the opportunity cost of capital and enterpreneurship. Less than a third of the total market margin is accounted for by the actual inputs (Ahmed 1983; FAO/Rapport 1986).

Again, given that 43% of the total cost represents market margin for the non-primary producers (traders) at the postharvest level, (33% of the consumer price) and considering that only a minimal amount of processing and product improvement is required, the gain of the non-primary producers is very significant. Producers (traders) at the secondary and tertiary levels of production are able to realize a larger pure profit or have a higher opportunity cost of their capital and labor than the primary producers (fishermen).

Sensitivity Analysis

Variation of Effort and Model Response

As mentioned earlier, the Base Model was solved without any prior restriction on the availability of effort. However, responses of the model to varying levels of effort would be useful to check its performance and consistency. More importantly, such exercise will allow us to identify values along paths of movements of shadow prices and other economic variables (e.g., catch, benefit, cost and price) for each of the individual fisheries as well as their aggregate.

Two types of variations in the availability of effort are examined. First, variations in the availability of aggregate effort in the Base Model are examined without any restriction on the allocation among various fisheries (species) and/or fishing grounds (river groups). This is assuming the flexibility characterizing effort allocation among species and fishing grounds. Thus, availability of aggregate effort in the base model is allowed to vary from zero to nonbinding levels.

Table 5.4. Aggregate values of different variables at various levels of total effort in the Base Model for riverine fisheries of Bangladesh.

	Level of total effort (gear hours x 10^6)					
Items	20,000	40,000	80,000	120,000	160,000	200,000
Benefit-cost[a]						
Net benefit	576	817	1,137	1,300	1,370	1,383
Gross benefit	1,295	2,138	3,272	4,302	5,116	5,634
Producer surplus	560	800	1,112	1,251	1,300	1,289
Consumer surplus	15	17	25	49	71	94
Total revenue	1,280	2,128	3,246	4,253	5,046	5,540
Total cost	719	1,321	2,135	3,002	3,746	4,251
-Harvest cost	326	654	1,097	1,636	2,090	2,435
-Postharvest cost	394	668	1,038	1,366	1,655	1,816
Catch-effort						
Total catch (t)	36,709	60,166	97,738	127,370	153,917	173,163
-direct catch	28,380	45,704	75,585	99,421	121,243	139,857
-by-catch	8,329	14,462	22,153	27,949	32,674	33,306
Total effort (gear hours x 10^6)	20,000	40,000	80,000	120,000	160,000	197,054
Catch per effort (kg/gear hour x 10^6)	1,835	1,504	1,222	1,061	962	879
Shadow price of effort (BDT/gear hour x 10^3)	17.64	10.75	5.89	2.46	0.74	0

[a]In million Bangladesh Taka (US$1 = BDT32).

A summary of results showing aggregate values of different variables at various levels of effort availability is shown in Table 5.4. A breakdown of the results for fisheries by species groups is shown in Table 48 - Appendix A. Fig. 5.2 shows the plot of aggregate catch and CPUE presented in Table 5.4. The curve of aggregate catch in Fig. 5.2 shows how catch would change as effort changes. The shape of the total catch curve shows that as effort increases, catch also increases but at a decreasing rate. This is consistent with the theoretical postulate that as more and more effort is exerted to a given level of stock, the marginal productivity of each additional effort, *ceteris paribus*, decreases, because of crowding externalities and vessel congestion relative to the availability of stock. Thus, CPUE also declines, as shown by the downward sloping curve in Fig. 5.2).

The plot of benefit and cost (harvest and postharvest cost) with effort and catch is shown in Figs. 5.3 and 5.4, respectively. The net benefit curve, defined as the difference between gross benefit and total cost in Figs. 5.3 and 5.4 increases at a decreasing rate and finally flattening out at 197,054 gear hours x 10^6 of effort and 173,163 t of catch. This suggests that additional units of effort beyond 197,054 gear hours x 10^6 will not increase the net benefit. In other words, the opportunity cost of effort becomes zero for this level of effort and output. In terms of the programming model this implies that the dual activity of effort will have a zero value reflecting a

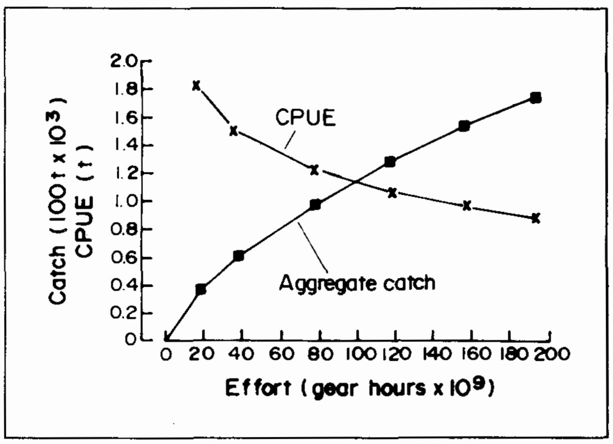


Fig. 5.2. Aggregate catch and effort relationships in the Base Model.

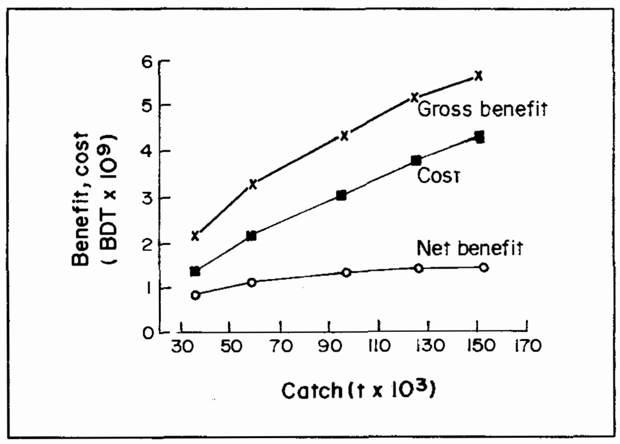


Fig. 5.3. Benefit, cost and effort relationships in the Base Model.

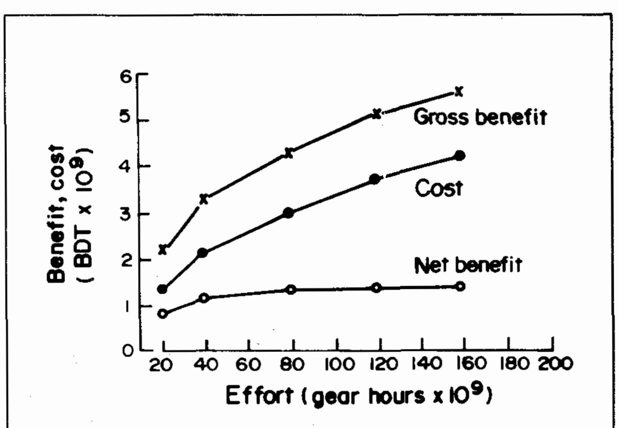


Fig. 5.4. Benefit, cost and catch relationships in the Base Model.

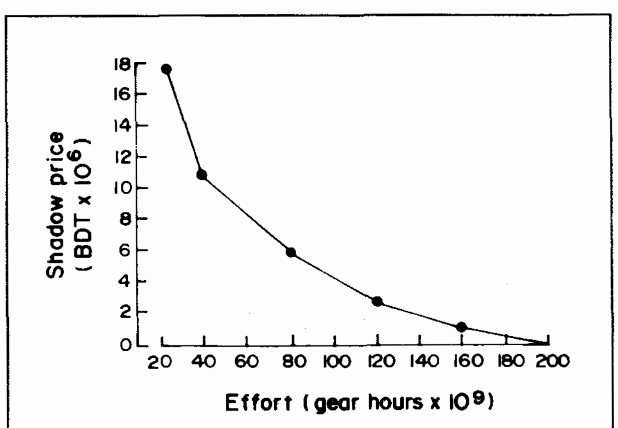


Fig. 5.5. Shadow prices of effort in the Base Model.

redundant character of the effort constraint beyond this limit. This is evident from Table 5.4 which also shows the shadow prices at various levels of aggregate effort. Fig. 5.5 shows the downward sloping curve for shadow prices of aggregate effort, signifying a diminishing contribution of effort at higher levels of its application to a given fish stock. Additionally (but this cannot be shown throughout this model), increased effort would increase the probability of recruitment failure, a biological consideration not discussed here.

Second, variations in the availability of effort are examined with prior restrictions on the allocation to each individual fishery. Thus, assuming fixed allocation of effort for each fishery the availability of such effort designated to each fishery (species groups) is allowed to vary from zero to nonbinding levels. There are, however, no prior bindings on allocation of effort among fishing grounds (rivers). This is considering that effort could be fishery-specific but flexible to operate in different fishing grounds. The implication of this case for management is that if fishing effort is allowed to move across species and fishing grounds and reallocation cost is minimal it would be profitable from a societal point of view to reallocate effort among species and fishing grounds until their shadow prices become equal. The results of the Base Model with unrestricted effort allocation show the optimal size of effort for each species in each river (Table 5.1).

Six different levels of effort allocation to each fishery were examined (Table 5.5). Figs. 5.6 and 5.7 show the total catch and CPUE for each fishery at various levels of effort. Total catch as well as CPUE is highest for the miscellaneous species fishery and lowest for the carp fishery for identical level of effort allocation to each fishery. For instance, at a level of 8,000 gear hours x 10^6 of effort available to each fishery the CPUE for the miscellaneous fishery is as high as 1,775 kg/gear hour x 10^6 while that for carp fishery is only 486 kg/gear hour x 10^6.

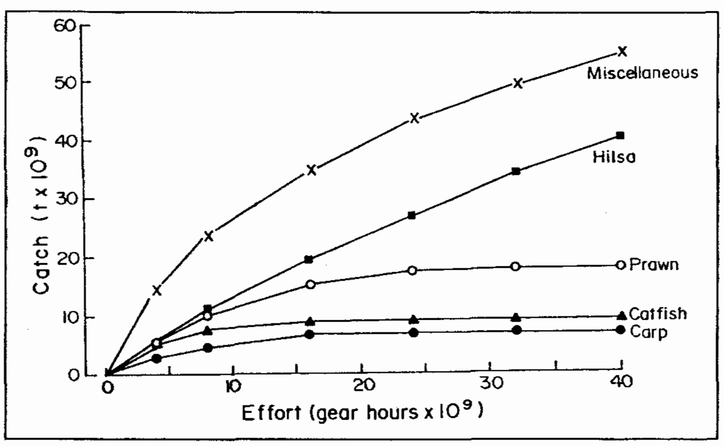


Fig. 5.6. Catch and effort relationships for individual groups in the Base Model.

The shadow prices of effort for each fishery are shown in Table 5.6 and Fig. 5.8. At a lower level of effort equal to 4,000 gear hours x 10^6 per fishery the shadow price of effort (gear hours x 10^9) for the miscellaneous fishery is the highest (BDT28.9 x 10^6) followed by hilsa (BDT15.6 x 10^6), prawn (BDT14.7 x 10^6), catfish (BDT13.8 x 10^6) and carp (BDT8.9 x 10^6). This implies that an additional unit of effort will yield the largest contribution to the net benefit if it is allocated to the carp fishery. As effort expands successively to each fishery, the shadow prices for each fishery diminishes. However,

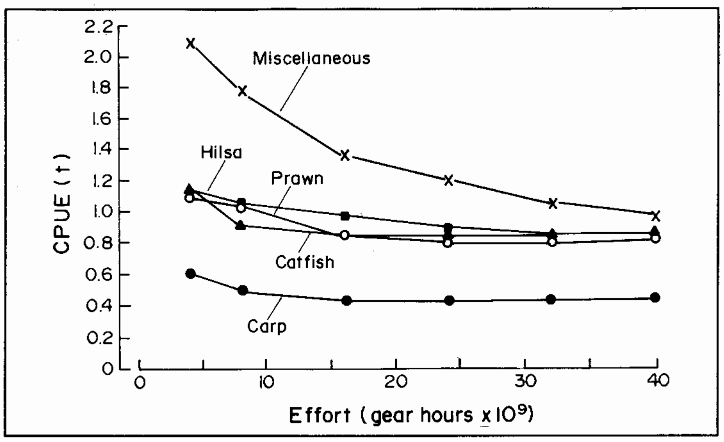


Fig. 5.7. CPUE and effort relationships for various groups in the Base Model.

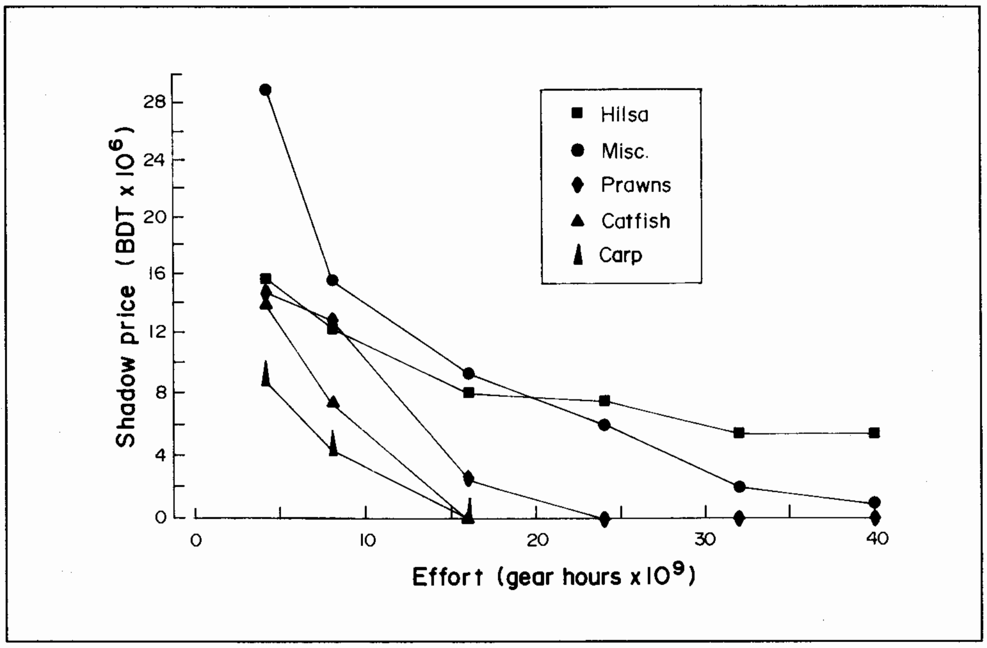


Fig. 5.8. Shadow prices of effort for various fisheries in the rivers of Bangladesh.

as seen in Fig. 5.8, although shadow prices diminish with increments in the level of effort the relative declines are different. Thus, at a higher level of effort equal to 24,000 gear hours x 10^6, hilsa exceeds miscellaneous fish in terms of shadow price of effort (gear hours x 10^9), the values being 7.34 and 5.95 million BDT, respectively. The shadow price for all other species are zero at 24,000 gear hours x 10^6 of effort available to each fishery. This signifies that if effort were increased above this figure, it would be a more rational choice to employ this to the hilsa fishery than to others, since extra effort contributes most to the net benefit when allocated to hilsa fishery. In fact, hilsa and miscellaneous fish have a positive shadow price for a wider range of effort than prawn, catfish and carp, implying the relatively greater capability of absorbing effort with positive net benefits.

Comparing the results of the first case where effort can move freely among fisheries with those of the second case in which effort allocation is fishery specific, it is observed

Table 5.5. Changes in effort (gear hours x 10^6) availability for each fishery in the Base Model for riverine fisheries of Bangladesh.

	E = 4,000						E = 8,000					
	Species						Species					
Items	Hilsa	Misc.	Prawn	Catfish	Carp	All	Hilsa	Misc.	Prawn	Catfish	Carp	All
Benefit-cost[a]												
Net benefit	83	238	109	39	52	521	155	372	148	39	67	782
Gross benefit	158	420	360	145	147	1,230	298	698	651	233	238	2,117
Producer surplus	82	238	108	38	50	517	149	363	142	36	61	751
Consumer surplus	0	0	1	0	2	4	6	9	6	3	6	31
Total revenue	157	420	359	145	145	1,226	292	689	645	230	232	2,087
Total cost	75	182	251	107	95	709	143	326	503	194	170	1,336
-Harvest cost	37	46	139	72	49	343	71	91	296	139	94	692
-Postharvest cost	38	137	111	35	46	366	72	235	207	54	76	643
Catch-effort												
Total catch (t)	5,955	14,436	5,535	4,957	2,843	33,726	11,053	23,702	9,986	7,876	4,644	57,261
- direct catch	4,519	8,411	4,348	4,607	2,394	24,279	8,440	14,200	8,157	7,284	3,886	41,967
- by-catch	1,436	6,025	1,187	350	449	9,447	2,613	9,502	1,829	592	758	15,294
Total effort[b] (hours)	4,000	4,000	4,000	4,000	4,000	20,000	8,000	8,000	8,000	8,000	8,000	40,000
Catch per effort[c] (kg)	1,130	2,103	1,087	1,152	599	1,686	1,055	1,775	1,020	911	486	1,432
Price and unit cost (BDT/per kg)												
Price[d]	26.44	29.10	48.94	29.24	50.92		26.40	29.06	48.50	29.15	49.89	
Harvest cost	6.27	3.18	25.15	14.47	17.23	10.18	6.43	3.84	29.66	17.70	20.35	12.09
Postharvest cost	6.32	9.46	20.12	7.05	16.06	10.86	6.48	9.92	20.70	6.88	16.34	11.24
Shadow price	15.55	28.88	14.69	13.77	8.86		12.03	11.28	12.58	7.39	4.37	

	E = 16,000						E = 24,000					
	Species						Species					
	Hilsa	Misc.	Prawn	Catfish	Carp	All	Hilsa	Misc.	Prawn	Catfish	Carp	All
Benefit-cost[a]												
Net benefit	251	460	186	36	69	1,002	316	507	196	40	73	1,132
Gross benefit	518	1,007	1,093	268	343	3,228	705	1,262	1,201	273	349	3,791
Producer surplus	248	455	129	35	56	923	310	499	182	39	60	1,090
Consumer surplus	3	5	57	1	13	78	5	8	14	1	13	42
Total revenue	515	1,002	1,036	267	330	3,150	700	1,255	1,187	272	336	3,749
Total cost	266	547	908	232	274	2,226	390	755	1,005	233	276	2,659
-Harvest cost	139	182	553	171	162	1,207	215	274	615	171	162	1,437
-Postharvest cost	128	365	354	61	112	1,019	175	481	389	62	114	1,222
Catch-effort												
Total catch (t)	19,592	34,576	15,251	9,165	6,781	85,365	26,788	43,412	17,505	9,329	6,911	103,945
- direct catch	15,530	21,613	13,559	8,280	5,799	64,781	21,305	28,657	14,310	8,280	5,799	78,351
- by-catch	4,062	12,963	1,692	885	982	20,584	5,483	14,755	3,195	1,049	1,112	25,594
Total effort[b] (hours)	16,000	16,000	16,000	9,831	13,742	71,573	24,000	18,285	9,831	13,742	89,858	
Catch per effort[c] (kg)	971	1,351	847	842	423	1,193	888	1,194	783	842	423	1,157
Price and unit cost (BDT/per kg)												
Price[d]	26.27	28.97	48.05	29.12	48.67		26.13	28.90	47.84	29.11	48.60	
Harvest cost	7.09	5.25	36.29	18.62	23.95	14.14	8.02	6.32	35.15	18.29	23.45	13.83
Postharvest cost	6.51	10.55	23.22	6.64	16.50	11.94	6.53	11.08	22.24	6.65	16.51	11.75
Shadow price	7.94	9.23	2.45	0	0		7.38	5.95	0	0	0	

	E = 32,000						E = 40,000					
	Species						Species					
	Hilsa	Misc.	Prawn	Catfish	Carp	All	Hilsa	Misc.	Prawn	Catfish	Carp	All
Benefit-cost[a]												
Net benefit	379	511	208	42	75	1,213	431	488	228	43	77	1,266
Gross benefit	893	1,427	1,219	275	351	4,164	1,049	1,573	1,220	277	354	4,472
Producer surplus	370	500	195	40	61	1,167	417	477	215	42	63	1,213
Consumer surplus	9	10	12	1	14	46	14	12	13	1	14	53
Total revenue	884	1,417	1,206	274	337	4,118	1,035	1,562	1,207	276	340	4,420
Total cost	514	917	1,011	233	276	2,950	618	1,085	992	234	277	3,206
- Harvest cost	292	361	616	171	161	1,601	357	455	596	171	161	1,739
- Postharvest cost	222	555	395	62	115	1,349	261	630	397	63	116	1,467
Catch-effort												
Total catch (t)	33,972	49,118	17,733	9,399	6,937	117,159	39,957	54,186	17,854	9,471	7,001	128,469
- direct catch	27,041	33,369	14,310	8,280	5,755	88,755	32,370	38,344	14,070	8,280	5,754	98,818
- by-catch	6,931	15,749	3,423	1,119	1,182	28,404	7,587	15,842	3,784	1,191	1,247	29,651
Total effort[b]	32,000	32,000	18,285	9,831	13,673	105,789	40,000	40,000	17,529	9,831	13,675	121,035
Catch per unit of effort (kg)[c]	845	1,043	783	842	421	1,107	809	959	803	842	421	1,061

continued

Table 5.5 (continued)

	E = 32,000						E = 40,000					
	Species						Species					
	Hilsa	Misc.	Prawn	Catfish	Carp	All	Hilsa	Misc.	Prawn	Catfish	Carp	All
Price and unit cost (BDT/kg)												
Price[d]	26.01	28.85	47.82	29.11	48.59		25.91	28.82	47.81	29.10	48.55	
Harvest cost	8.59	7.36	34.73	18.16	23.26	13.67	8.93	8.39	33.37	18.02	23.05	13.54
Postharvest cost	6.54	11.30	22.27	6.65	16.52	11.52	6.54	11.63	22.21	6.65	16.51	11.42
Shadow price	5.25	1.97	0	0	0							

[a]In million Bangladesh Taka (US$1 = BDT32).
[b]In gear hours x 10^6.
[c]Ratio of direct catch to total effort.
[d]As for prawn price indicates that of only small prawns; price of large prawns is fixed at BDT177/kg.

Table 5.6. Shadow prices of effort for various fisheries (Dual value in million BDT).

Available effort in each fishery (gear hours x 10^6)	Shadow price (gear hours x 10^9)				
	Hilsa	Prawn	Catfish	Carp	Misc.
4,000	15.55	14.69	13.77	8.86	28.88
8,000	12.03	12.58	7.39	4.37	15.28
16,000	7.94	2.45	0.00	0.00	9.23
24,000	7.38	0.00	0.00	0.00	5.95
32,000	5.25	0.00	0.00	0.00	1.97
40,000	5.25	0.00	0.00	0.00	0.89
Level of effort at which Dual value becomes zero	111,321	18,285	9,831	13,675	45,939

that a nonspecific effort allocation can bring higher net benefit to the society and a larger catch per unit of effort at all levels of effort availability. This is because, given that efforts are flexible, a nonspecific effort allocation would make interspecies allocation of effort in such a way that efforts will move from fisheries with lower shadow prices to fisheries with higher shadow prices. The process will continue until shadow prices in all fisheries become equal. For instance, as seen in Tables 5.5 and 5.6, when a total of 20,000 gear hours x 10^6 of effort are specified to be allocated equally among five existing fisheries, the shadow price of effort (expressed in gear hours x 10^9) for the miscellaneous fishery is the highest (BDT28.88 million) while that for carp is the lowest (BDT8.86 million). On the other hand, as shown in Table 5.4, when the same effort is made unrestricted, the interspecies allocation will equate the shadow price of effort (gear hours x 10^9) to BDT17.64 million for all fisheries, making the highest allocation to the miscellaneous fishery (7,274 gear hours x 10^6) and the lowest allocation for carp (988 gear hours x 10^6).

Here again, it must be stressed that the increase of effort directed, e.g., against hilsa could actually lead to a rapid drop of catch and profits due to a failure of recruitment, an element not considered in the model.

Table 5.7. Behavior of the riverine fisheries of Bangladesh under alternative cost conditions (changes in the cost of harvesting from the Base Model).

Items	Condition of cost					
	50% decrease	25% decrease	Base Model	25% increase	50% increase	100% increase
Benefit-cost[a]						
Net benefit	2,808	2,258	1,383	929	642	330
Gross benefit	10,712	8,099	5,634	4,153	3,041	1,661
Producer surplus	2,163	1,653	1,289	873	616	321
Consumer surplus	645	605	94	55	25	9
Total revenue	10,066	7,494	5,540	4,097	3,016	1,652
Total cost	7,904	5,841	4,251	3,224	2,399	1,331
-harvest cost	3,186	2,918	2,435	1,929	1,456	819
-postharvest cost	4,718	2,922	1,816	1,295	943	512
Catch-effort						
Total catch ('000 kg)	305.65	230.06	173.16	130.23	96.58	54.13
-direct catch	245.87	184.26	139.86	104.67	77.36	44.30
-by-catch	59.77	45.80	33.31	25.56	19.22	9.83
Total effort (hours)[b]	483,363	303,101	197,054	131,493	84,671	38,787
Catch per effort (kg/ gear hour x 10^6))	632	759	879	990	1,141	1,396

[a]In million Bangladesh Taka (US$1 = BDT32).
[b]In gear hours x 10^6.

Simulation of Cost and Demand Changes and Implications for Policy

In the supply-demand framework of the programming model, most of the policy and factor changes will affect the outcome through changes in the cost and price structure of the fisheries. Therefore, in the following sections efforts have been made to analyze the effects of changes in the cost and demand structure of the Base Model in terms of behavior of the fisheries. Cost changes include shifts in the harvesting cost, while demand changes include changes in the aggregate price.

CHANGES IN THE COST OF HARVEST

The structure of cost functions for harvesting various species of fish from the rivers of Bangladesh was analyzed by performing systematic changes in the harvest cost functions used in the Base Model. Such changes were done in both directions (increase and decrease) from the level of Base Model harvest-cost functions.

Table 5.7 shows the aggregate results of variations of cost of harvesting in percentage terms of the Base Model costs. As seen in Table 5.7 a 25% decrease in the cost of harvest would allow aggregate efforts in the riverine fisheries of Bangladesh to expand by 54%, theoretically increasing the total landings by 33% and total net benefit by 63% from the levels shown by the results of the Base Model. However, the net benefit accrued would contribute more (in terms of percentage increase) to consumer surplus than to producer surplus. Thus, as a result of a 25% decrease in the cost condition of harvest, consumer surplus would increase by more than 500% (an increase from BDT94 million to BDT607 million) while producer surplus would increase by only 25% (an increase from BDT1,289 million to BDT1,653 million) from the Base Model levels.

Table 5.10. Changes in the availability of effort for a 25% decrease in the cost of harvest from the Base Model for riverine fisheries of Bangladesh.

	Level of total effort (gear hours x 10^6)					
Items	20,000	40,000	80,000	120,000	200,000	303,101
Benefit-cost[a]						
Net benefit	677	1,007	1,442	1,765	2,126	2,258
Gross benefit	1,475	2,309	3,676	4,869	6,661	8,099
Producer surplus	671	985	1,281	1,519	1,631	1,653
Consumer surplus	7	22	161	246	495	605
Total revenue	1,469	2,287	3,515	4,623	6,166	7,494
Total cost	798	1,302	2,234	3,104	4,535	5,841
-Harvest cost	339	570	975	1,415	2,106	2,918
-Postharvest cost	459	732	1,259	1,689	2,429	2,922
Catch-effort						
Total catch ('000 t)	37.35	61.71	99.10	131.88	184.09	230.06
-direct catch	27.52	45.67	75.27	102.18	144.52	184.26
-by-catch	9.84	16.04	23.83	29.70	39.57	45.80
Total effort[b]	20,000	40,000	80,000	120,000	200,000	303,101
Catch per unit of effort (kg/gear hour x 10^6)	1,867	1,543	1,239	1,099	920	759
Shadow price of effort (BDT/gear hour x 10^3)	20.99	13.06	9.52	6.15	2.72	0

[a]In million Bangladesh Taka (US$1 = BDT32).
[b]In gear hours x 10^6.

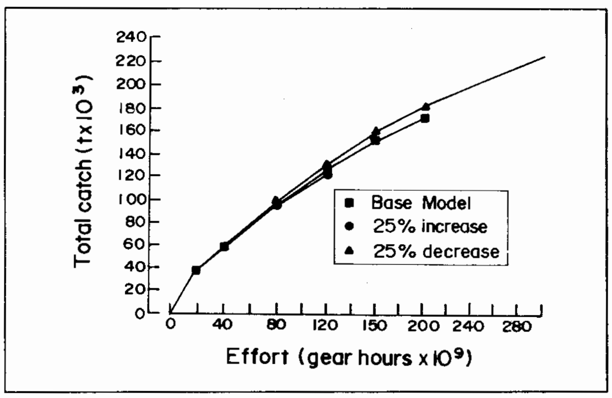


Fig. 5.9. Catch and effort under alternative cost conditions.

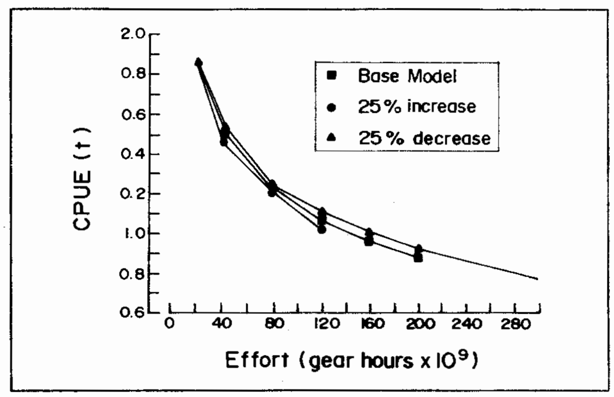


Fig. 5.10. CPUE and effort under alternative cost conditions.

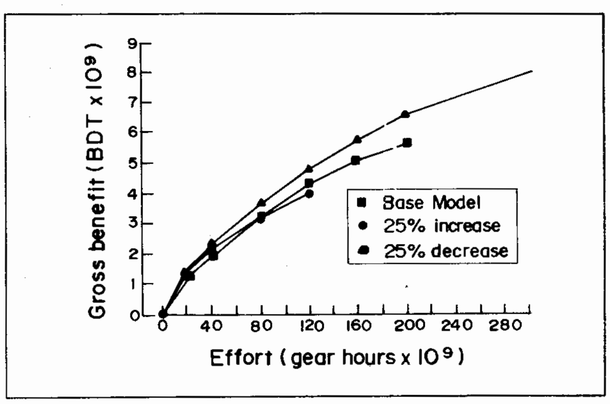


Fig. 5.11. Gross benefit and effort under alternative cost conditions.

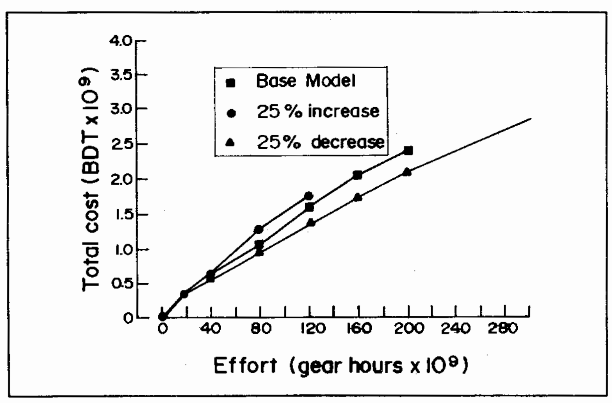


Fig. 5.12. Cost and effort under alternative cost conditions.

As shown in Fig. 5.9 the movement of total landings at varying levels of effort availability under alternative cost conditions follows a steady pattern. A higher amount of total catch is predicted - again under the assumption of no stock-recruitment relationship - for higher levels of effort with catch increasing at a diminishing rate for all situations of cost. This implies a downward sloping curve of CPUE for all cost conditions, as shown in Fig. 5.10. Furthermore, as observed in Fig. 5.9, a higher total catch would be obtained at each given level of effort when the cost condition decreases and vice versa. This results in an increase in the CPUE when cost condition decreases and vice versa, particularly for relatively higher level of effort availability. Thus, as shown in Fig. 5.10, the CPUE curve would shift up for a decrease in the condition of cost and vice versa. This situation is equivalent to a stock change in a given fishing environment with resultant change in the CPUE, and a change in the cost of harvest. Therefore, the simulation of alternative cost conditions of harvest can as well be attributed to stock changes, with the resultant outcome being similar to cost changes.

A similar pattern is observed in the case of gross benefit and net benefit shown in Figs. 5.11 and 5.13, respectively. Thus, gross revenue as well as net revenue would be higher for lower cost conditions for all levels of effort availability and vice versa.

As for the cost of harvest (effort cost), shown in Fig. 5.12, however, the movement is still steady but the relationship is positive. A lower total cost of effort is incurred at lower levels of cost conditions and vice versa. This is because a change in the cost condition of harvest would also change the unit cost of effort proportionately.

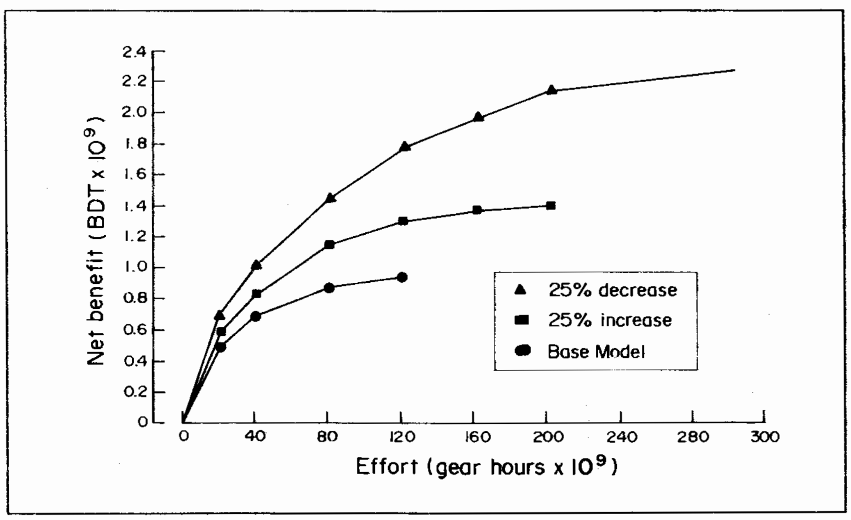


Fig. 5.13. Net benefit and effort relationships under alternative cost conditions.

Also, when cost conditions change, the allocation pattern of effort across fisheries changes. This is evident from Table 5.11. The inter-species reallocation of effort under alternative cost conditions would also produce differing effects on the pattern of landings of each individual species. For instance, for hilsa higher catches are recorded at higher cost conditions, whereas for prawn, lower catches are recorded at higher cost conditions, for a given level of aggregate effort (Table 5.11). The implication of such results is that if several interdependent fisheries are exploited by effort that is flexible to reallocation across fisheries, changes in the condition of cost of harvest may change

Table 5.11. Behavior of effort (gear hours x 10^6) use and landings (t) of individual species at various levels of effort availability and under alternative cost conditions.

Available level of effort (gear hours x 10^6)	Cost Condition: 25% increase				25% decrease				Base Model			
	Effort	Direct catch	By-catch	Total catch	Effort	Direct catch	By-catch	Total catch	Effort	Direct catch	By-catch	Total catch
Hilsa												
20,000	5,570	6,000	1,691	7,691	1,041	1,122	2,113	3,235	5,570	6,000	1,715	7,715
40,000	14,791	14,500	2,621	17,121	6,091	6,500	3,343	9,843	9,130	9,294	2,997	12,291
80,000	35,280	29,228	4,786	34,014	27,479	22,377	4,875	27,252	31,099	2,6353	5,014	31,367
120,000	65,816	46,978	5,134	52,112	48,258	38,000	6,752	44,752	57,846	42,660	5,630	48,290
160,000	77,045	52,560	5,150	57,710		-	-	-	79,916	55,180	7,469	62,649
200,000					87,558	59,669	10,534	70,203	111,321	70,350	7,811	78,161
303,101					173,194	92,483	10,517	103,000				
Prawn												
20,000	3,261	3,561	1,462	5,023	7,996	8,153	1,480	9,633	3,763	4,120	1,453	5,573
40,000	3,763	4,120	2,242	6,362	10,858	10,106	2,359	12,465	8,003	8,160	2,323	10,483
80,000	8,003	8,160	3,009	11,169	16,056	13,700	3,053	16,753	8,652	8,510	3,117	11,627
120,000	8,003	8,160	3,237	11,397	23,685	18,492	3,311	21,803	15,113	13,160	3,260	16,420
160,000	8,050	8,200	3,240	11,440		-	-	-	16,751	13,810	3,780	17,590
200,000					27,355	19,610	4,814	24,424	16,804	13,850	4,131	17,981
303,101					33,931	23,670	4,978	28,648				
Catfish												
20,000	2,405	3,200	349	3,549	2,405	3,200	408	3,608	2,405	3,200	347	3,547
40,000	4,733	5,000	449	5,449	5,683	5,640	608	6,248	5,531	5,520	539	6,059
80,000	5,531	5,520	782	6,302	8,422	7,560	910	8,470	8,257	7,440	813	8,253
120,000	8,436	7,520	922	8,442	9,096	7,960	1,172	9,132	9,149	7,880	1,060	8,940
160,000	8,436	7,520	966	8,486		-	-	-	9,336	7,960	1,270	9,230
200,000					10,837	8,730	1,545	10,275	9,336	7,960	1,321	9,281
303,101					11,069	8,850	1,868	10,718				
Carp												
20,000	1,049	940	438	1,378	1,296	1,730	475	2,205	988	910	443	1,353
40,000	1,208	1,047	631	1,678	1,259	1,710	801	2,511	1,354	1,134	749	1,883
80,000	4,816	2,673	909	3,582	4,319	3,128	1,105	4,233	5,127	2,782	1,018	3,800
120,000	9,077	4,251	1,052	5,303	8,031	4,527	1,284	5,811	9,224	3,921	1,589	5,510
160,000	9,294	4,588	851	5,439		-	13,673	5,753	1,322	7,075		
200,000					12,419	5,914	1,586	7,500	13,654	5,741	1,372	7,113
303,101					23,514	8,757	1,757	10,514				

the effort allocation and landings pattern of individual fisheries, depending on the opportunity cost of effort relative to the CPUE in each fishery.

The shadow price of effort for alternative cost conditions are shown in Table 5.12 and plotted in Fig. 5.14. It is seen from Table 5.12 that the shadow prices of effort are lower for a cost increase and higher for a cost decrease at a given level of effort. In

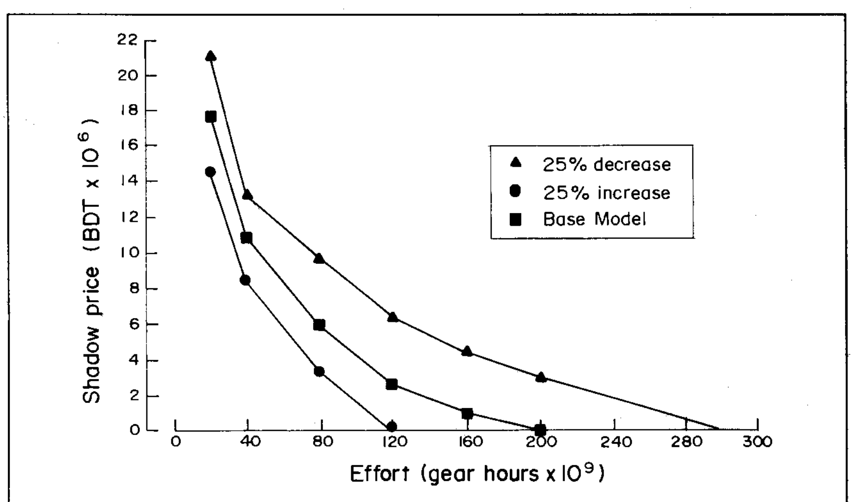


Fig. 5.14. Shadow prices of effort under alternative cost conditions.

Table 5.12. Shadow prices (BDT x 10^6 per gear hour x 10^9) of effort under alternative conditions of cost of harvest.

Available effort (gear hours x 10^6)	Cost condition		
	25% increase	25% decrease	Base Model
20,000	14.48	20.99	17.64
40,000	8.41	13.06	10.75
80,000	3.25	9.52	5.89
120,000	0.2	6.15	2.46
160,000	0	-	0.74
200,000		2.72	0
303,101			0
Level of effort at which Dual value becomes zero	131,493	303,101	197,054

terms of Fig. 5.14 this implies that an increase in the cost condition of harvest would shift the curve of shadow price down and vice versa. The implication of such movements of shadow prices across different cost conditions are that each additional unit of effort would result in a larger contribution to the net benefit when applied to a cost situation that is lower than the one assumed in the Base Model and vice versa.

CHANGES IN AGGREGATE DEMAND

Changes in the retail demand functions for various species of fish were simulated by changing the intercepts of the functions. Such changes imply changes in the aggregate demand attributable to changes in the population, real income, etc. The intercepts were shifted up and down by 10% and 20% from the Base Model demand intercepts.

Table 5.13 shows the aggregate outcome under alternative demand conditions. A decrease in the aggregate demand would reduce the level of effort while an increase in the aggregate demand would increase the level of effort as compared to the Base Model. The resultant effects on the landings (total catch), total cost and net benefit (producer and consumer surplus) would also be positive. As seen in Table 5.13 a 10% decrease in the aggregate demand for all fish species would decrease the level of effort by 28% from the Base Model level. This would reduce the total catch, total cost and net benefit by 20%, 26% and 32%, respectively. A 10% increase in the aggregate demand would increase the level of effort by 26% from the Base Model level. The model predicts that this would increase the total landings by 19%, total cost by 26% and total net benefits by 52%. Also since the level of effort changes with the changes in the aggregate demand, the CPUE would also change. Accordingly, the CPUE for the operating fishing units would be higher for a decrease in the aggregate demand and vice versa.

As for the individual fisheries, the effects of changes in the aggregate demand on total effort and total catch would also be positive (Table 52 - Appendix A). Effort use and landings would increase for all species if aggregate demand increases and vice versa. However, relative effects of a given change in aggregate demand would be different for each fishery. Table 5.14 shows the catch (direct catch and by-catch), price and effort for individual fisheries under alternative demand conditions. As for effort use, a 10% decrease in aggregate demand from the Base Model level would decrease the effort use in carp, prawn and hilsa fisheries by as much as 36%, 32% and 30%,

Table 5.13. Behavior of different riverine fisheries of Bangladesh under alternative demand conditions (changes in the demand intercept from the Base Model).

Items	20% increase	10% increase	Base Model	10% decrease	20% decrease
Benefit-cost[a]					
Net benefit	2,619	2,099	1,383	935	561
Gross benefit	8,978	7,459	5,634	4,082	2,827
Producer surplus	2,443	1,973	1,289	878	529
Consumer surplus	176	126	94	58	32
Total revenue	8,802	7,333	5,540	4,024	2,795
Total cost	6,359	5,360	4,251	3,147	2,267
-Harvest cost	3,811	3,185	2,435	1,742	1,184
-Postharvest cost	2,548	2,175	1,816	1,405	1,083
Catch-effort					
Total catch (t)	232,045	206,610	173,163	139,072	105,254
-direct catch	186,050	164,847	139,857	110,071	83,498
-by-catch	45,995	41,763	33,306	29,001	21,756
Total effort[b] (hours)	310,900	247,995	197,054	142,178	91,250
Catch per effort[c] (kg/gear hour x 10^6)	746	833	879	978	1,153

[a]In million Bangladesh Taka (US$1 = BDT32).
[b]In gear hours x 10^6.
[c]Ratio of total catch to total effort.

Table 5.14. Total catch, price and effort for individual species under alternative demand conditions.

Species	10% decrease Catch (t)	10% decrease Price (BDT/kg)	10% decrease Effort (hours)[a]	Base Model Catch (t)	Base Model Price (BDT/kg)	Base Model Effort (hours)[a]	10% increase Catch (t)	10% increase Price (BDT/kg)	10% increase Effort (hours)[a]
Hilsa	59,816 (52,930)[b]	22.91	77,825	78,161 (70,350)	25.26	111,321	86,023 (74,900)	27.79	122,932
Prawn[c]	12,946 (9,560)	43.32	11,411	17,981 (13,850)	47.79	16,804	23,720 (18,560)	52.21	24,205
Catfish	9,017 (7,960)	26.18	9,336	9,281 (7,960)	29.11	9,336	10,413 (8,730)	32.02	10,837
Carp	5,602 (4,421)	44.09	8,775	7,113 (5,741)	48.49	13,654	8,974 (7,333)	52.68	17,723
Misc.	51,690 (35,200)	25.91	34,831	60,627 (41,956)	28.76	45,939	77,480 (55,324)	31.55	72,298
Total	139,072 (110,071)		142,178	173,163 (139,857)		197,054	206,610 (164,847)		247,995

[a]In gear hours x 10^6.
[b]Figures in parentheses indicate the direct catch.
[c]Price indicates that of small prawns only.

respectively, whereas there would be no change in the effort in the catfish fishery as compared to the effort levels for the respective fisheries in the Base Model. Again, a 10% increase in aggregate demand would increase the effort in the prawn fishery, for instance, by as high as 44%, whereas there would be only 10% increase in the effort in the hilsa fishery.

With respect to catch as an outcome of effort use, particularly direct catch, the response of individual fisheries is different for changes in aggregate demand. Thus, as shown in Table 5.14, a 10% decrease in aggregate demand would result in a decline of direct catch of prawn, hilsa and carp by as much as 31%, 25% and 23%, respectively, whereas that of catfish would remain unchanged at the Base Model level. Similarly, a 10% increase in aggregate demand would increase the direct catch of prawn, miscellaneous fish and carp by as much as 34%, 32% and 28% respectively, whereas that of hilsa and catfish would only increase by 6% and 10%, respectively. The behavior of catch and effort to changes in aggregate demand, therefore, shows that prawn and carp fisheries are more sensitive to demand changes (in both directions), while the hilsa fishery is more sensitive for a decrease in aggregate demand.

Also, as expected, the equilibrium prices of all species would increase when demand increases and vice versa. Thus, as shown in Table 5.14, a 10% decrease in the aggregate demand would increase equilibrium price for hilsa by 10%, while a 10% decrease in the aggregate demand would reduce that of hilsa by 9.3%. The effects on prices of other groups is similar in magnitude, ranging between 8.6% and 10% for both increase and decrease in aggregate demand.

The behavior of the riverine fisheries for various given levels of effort under alternative demand conditions was also simulated through sensitivity analysis. The outcomes for each level of effort under alternative demand conditions show how the individual fisheries as well as their aggregate grow, responding to alternative market (demand) conditions. Effects of 10% changes from the Base Model are shown in Tables 5.15 and 5.16.

The movement of aggregate catch, CPUE and benefit (gross benefit) and cost of harvesting at varying levels of available effort and under alternative demand conditions are shown in Figs. 5.15 to 5.18, respectively. At lower levels of effort, aggregate catch,

Table 5.15. Changes in the availability of effort for a 10% decrease in the aggregate demand from the Base Model for riverine fisheries of Bangladesh.

	Level of total effort (gear hours x 10^6)				
Items	20,000	40,000	80,000	120,000	142,178
Benefit-cost					
Net benefit[a]	468	628	841	921	935
Gross benefit	1,212	2,019	2,891	3,697	4,082
Producer surplus	463	616	815	876	878
Consumer surplus	4	12	26	46	58
Total revenue	1,208	2,007	2,865	3,652	4,024
Total cost	745	1,391	2,050	2,776	3,147
-Harvest cost	343	683	1,063	1,513	1,742
-Postharvest cost	402	708	987	1,262	1,405
Catch-effort					
Total catch (t)	37,760	61,854	95,645	124,742	139,072
-direct catch	28,026	46,367	75,807	99,414	110,071
-by-catch	9,734	15,487	19,838	25,328	29,001
Total effort[b] (hours)	20,000	40,000	80,000	120,000	142,178
Catch per effort[c] (kg/gear hour x 10^6)	1,888	1,546	1,196	1,040	978
Shadow price of effort (BDT/gear hour x 10^3)	14.8	6.08	4.39	0.77	0

[a]In million Bangladesh Taka (US$1 = BDT32).
[b]In gear hours x 10^6.
[c]Ratio of total catch to total effort.

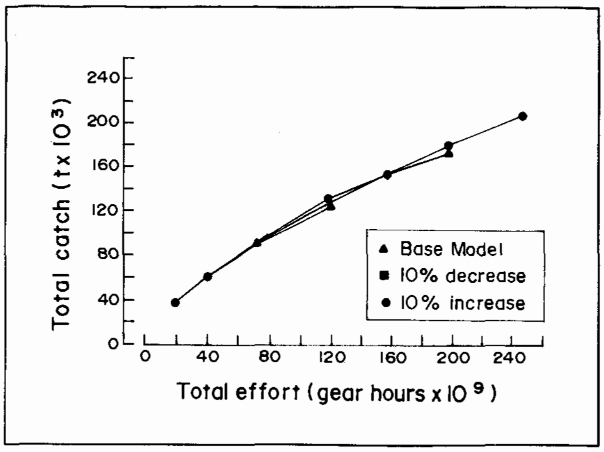


Fig. 5.15. Catch and effort under alternative demand conditions.

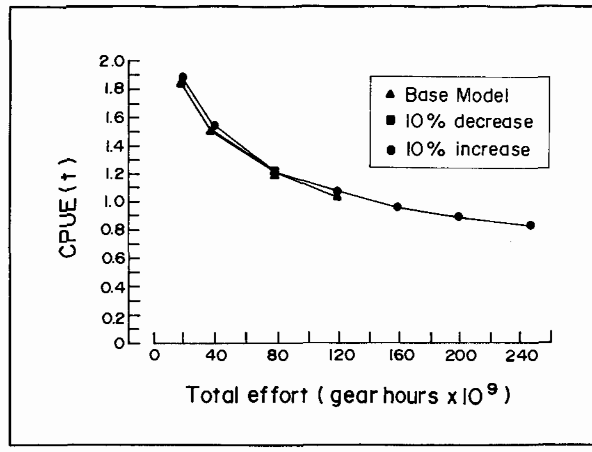


Fig. 5.16. CPUE and effort under alternative demand conditions.

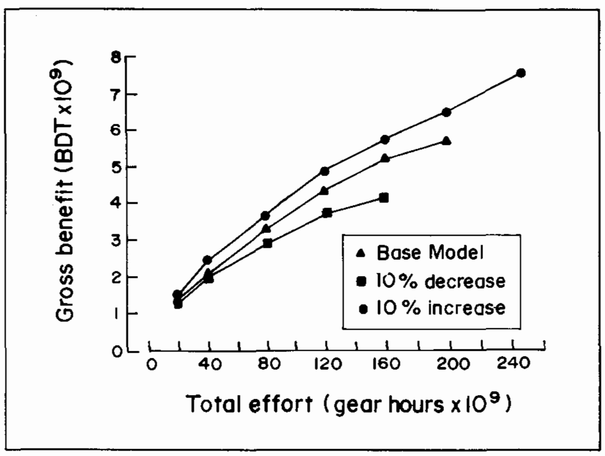


Fig. 5.17. Gross benefit and effort under alternative demand conditions.

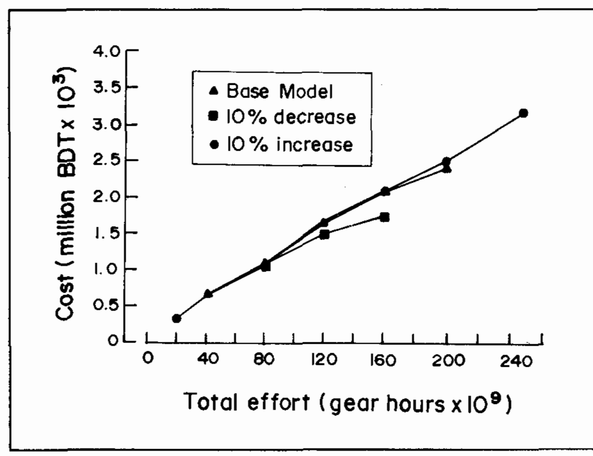


Fig. 5.18. Cost and effort under alternative demand conditions.

CPUE and cost of harvesting show little or no change under alternative demand conditions. Gross benefits are higher for higher levels of aggregate demand and vice versa. Consequently, net benefits shown in Fig. 5.19 would be higher at higher levels of aggregate demand. This is due mainly to the higher levels of equilibrium price showing higher willingness of consumers to pay.

The behavior of each fishery under two alternative demand conditions (10% decrease and increase) for varying levels of effort availability is shown in Tables 53 and 54 - Appendix A.

The shadow prices of effort under alternative demand conditions are shown in Fig. 5.20. At a given level of effort, the shadow prices of effort would be higher for higher levels of aggregate demand and vice versa, provided that effort is a binding variable. Also, in all cases of demand conditions the shadow prices would fall as the level of available effort increases. The implication of this result is that when demand condition improves through an increase in the aggregate demand each unit of effort would have a higher positive contribution to the net benefit. As a result, the limit to which effort could be expanded in order to achieve higher net benefit simultaneously would be higher. In other words, the shadow price of effort would become zero at a higher level of its use if aggregate demand increases. Thus, as seen earlier in Table 5.13, the

Table 5.16. Changes in the availability of effort for a 10% increase in the aggregate demand from the Base Model for riverine fisheries of Bangladesh.

	Level of total effort (gear hours x 10^6)					
Items	20,000	40,000	80,000	120,000	160,000	200,000
Benefit-cost[a]						
Net benefit	710	1,034	1,437	1,711	1,860	1,935
Gross benefit	1,455	2,423	3,553	4,797	5,650	6,419
Producer surplus	706	1,021	1,411	1,666	1,785	1,838
Consumer surplus	4	13	26	45	75	97
Total revenue	1,450	2,410	3,528	4,752	5,575	6,322
Total cost	745	1,389	2,117	3,086	3,790	4,484
-Harvest cost	343	683	1,096	1,693	2,119	2,541
-Postharvest cost	402	706	1,021	1,393	1,672	1,943
Catch-effort						
Total catch (t)	37,760	61,928	97,274	130,188	155,440	179,621
-direct catch	28,026	46,498	75,906	103,672	121,730	143,693
-by-catch	9,734	15,430	21,368	26,516	33,710	35,928
Total effort[b] (hours)	20,000	40,000	80,000	120,000	160,000	200,000
Catch per effort[c] (kg/gear hour x 10^6)	1,888	1,548	1,216	1,085	972	898
Shadow price of effort (BDT/gear hour x 10^3)	22.58	14.67	9.6	4.55	2.98	1.43

[a]In million Bangladesh Taka (US$1 = BDT32).
[b]In gear hours x 10^6.
[c]Ratio of total catch to total effort.

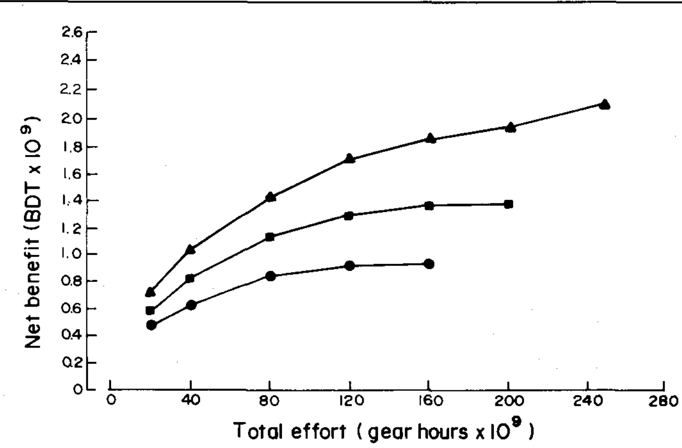


Fig. 5.19. Net benefit and effort relationships under alternative demand conditions.

optimal level of effort is higher for increases in aggregate demand while lower for decreases in the aggregate demand.

Implications

The above results of cost and demand changes can be interpreted in terms of policy and factors that affect the bioeconomic and technological variables as well as those on the demand side of the market. Such factors include resource availability, CPUE, cost of fishing inputs, postharvest handling and processing costs, and market

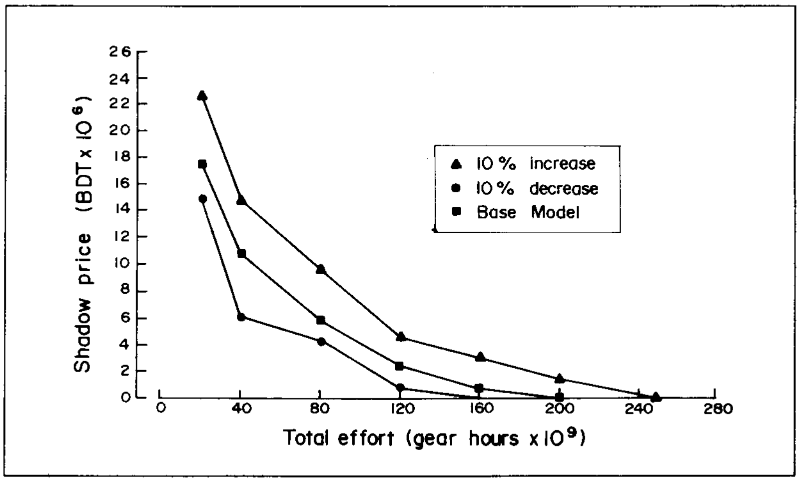


Fig. 5.20. Shadow prices of effort under alternative demand conditions.

prices for fish and fish products. In terms of the model any policy would result in some parametric changes to the functional equations affecting directly or indirectly the CPUE, cost per unit of effort and output, and prices, (revenues and benefits). For instance, the impact of a stock reduction or stock enhancement can be viewed either in terms of a change in the catchability coefficient or a proportionate change in the CPUE. This in turn would imply a proportionate change in the cost per unit of catch. Similarly, a technological change that would increase the fishing power of the individual units of effort will imply some change (a short-term increase) in CPUE and hence, a decrease in the cost per unit of catch, if not cost per unit of effort. Further, a change in the price of constituent effort will affect the cost per unit of effort, and hence the cost per unit of catch. Similarly, changes in the aggregate demand and a change in consumer taste can be viewed in terms of a shift of the demand (intercept changes) and a change in the slope of the demand function, respectively. In effect, almost all changes in policy or management variables influence costs and or prices.

CHAPTER 6
POLICY IMPLICATIONS AND CONCLUSION

In Bangladesh riverine fisheries, the major concern is the presence of an oversized effort capacity (118%). Given that effort could be reduced to economically efficient levels (represented by the results of the Base Model) the existing riverine fisheries are capable of generating substantial net benefits (BDT1,383 million per annum) of which 96% accrues to producer surplus. Under the traditional management through leasing to private individuals such benefit/surplus is either lost (at least partly) due to the overcapacity of the fishing fleet or captured (partly) as monopoly profits by the lease holders who act as middlemen between the resource owner (government) and the fishers. The government gets only a token amount of this benefit through open auctions of fishery rights.

Intervention into the system by a management entity capable of controlling the intensity of effort would help tap substantial positive net benefits from these fisheries. The surpluses could be used to support management costs and the program of effort reduction, including rehabilitation of displaced workers/fishers. The relative capacity of various fisheries and fishing grounds in generating this surplus can be made a basis for taxing purposes.

In the government's ongoing thrust to manage fisheries through a restrictive licensing system (under the New Fisheries Management Policy) uniformity of fees charged can be obtained by evaluating the relative benefit potentials of fisheries across river systems and environments. In other words, a differential intensity has to be applied with regard to taxation. Thus, fisheries and/ or fishing grounds which have more benefit potential would require more taxation than those of less potential. On the basis of the results obtained from the Base Model, an estimate of the benefit potential of each individual fishery can be made in terms of producer surplus per unit of effort. Thus, the prawn fishery can be ranked as having the largest potential (BDT13,925/gear hour x 10^6), followed by miscellaneous fish (BDT10,753/gear hour x 10^6), catfish (BDT5,141/gear hour x 10^6), carp (BDT4,834/gear hour x 10^6) and hilsa (BDT4,015/gear hour x 10^6), respectively. Therefore, the highest rate of taxation should be on prawn fishing followed by miscellaneous fish, catfish, carp, and hilsa fishing.

Again, there are distributional implications of this surplus: provided that the surpluses are not fully taxed away this will raise the income level of the sectoral participants who will be allowed to remain in the fishery.

Finally, the present model sheds light on issues that require careful consideration in the government's management plans. Such issues include: ensuring a balance among regions and rivers in terms of effort allocation and benefit generation, and an equity in the distribution of benefits among primary producers (fishers), the trading and middlemen communities, and consumers.

While it is true that management can capture the fisheries benefits either partly or wholly through an appropriate rate of taxation on either inputs (effort), output or both to maintain an optimal level of effort, it is also necessary to improve landing, transport and communication infrastructures to correct the discriminatory cost and revenue structures between regions of fish harvest as well as between sectoral participants (e.g., fishers and postharvest operators), and thereby ensure a balance in the distribution of benefits and/or profits among interest groups.

The previous chapters have developed a programming model of a fishery sector through which an assessment of the benefit potentials of fisheries exploitation and its end uses can be evaluated. Application of a programming technique is productive to analyze behavior of fisheries under alternative technoeconomic and market (price) conditions. However, despite the considerable extent in the programming framework of the model, its implementation has been limited to few interacting elements in the fishery process. This is due to the shortage of information on both biological and economic aspects of the riverine fisheries of Bangladesh. As such, on the basis of the short-run observations on the variables, the implications of the results for long-term behavioral stability of the fisheries require testing by future investigations. Particularly, model outputs referring to the yields and/or benefits that could be taken given an *increase* of present fishing effort must be taken with a grain of salt, because the model did not consider the impact of reduced (adult) broodstock on the production of (juvenile) recruits.

Such investigations would include scientific assessments of the level of stocks of important species and its dependence on the regime of the rivers, stock-recruitment relationships, study of the relationship between gear heterogeneity and fishing mortality across species and seasons, and the analysis of factors and channels of postharvest activities. If the information necessary for the analysis can be generated, the framework of the model can be expanded to include other bioeconomic systems (e.g., beels, floodlands, lakes and ponds).

ACKNOWLEDGEMENTS

This report is based on my Ph.D. thesis at Universiti Pertanian Malaysia (UPM). I would like to acknowledge the financial assistance of Ford Foundation and Winrock International toward the publication of this report.

I am thankful to the late Dr. Ian Smith and to Dr. Daniel Pauly, Dr. Roger Pullin, and Mr. Jay Maclean, and other ICLARM staff for their support and friendship while preparing this report.

Special thanks to Mr. Jay Maclean, Dr. D. Pauly and Ms. Letty Dizon for editing the manuscript and to Messrs. Ovidio Espiritu, Jr., Chris Bunao and Albert Contemprate for assisting with the drawings.

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Appendix A
Tables 33 to 54

Table 33

Area of Large Water Bodies in Each Region of Bangladesh by District (sq km)

Region/ District	Rivers and Estuaries: Meghna	Padma	Jamuna-B.Putra	Others	Total	Baor, Beel & Lakes	Grand Total
Northeast							
Sylhet	0			208.0	208	327.0	535
Mymensingh	15		51.8	288.2	355	294.1	649
Comilla	276	5.4		113.5	395	11.0	406
Tangail		126.5	69.9	61.4	258	23.3	281
Dhaka	143		29.5	174.3	347	49.2	396
Southeast							
Noakhali	68			889.5	957		957
Chittagong				600.1	600	0.9	601
Ctg. Hills				205.7	206	691.7	897
Northwest							
Pabna		88.6	240.9	84.3	414	32.6	446
Bogra			98.2	39.1	137	38.0	175
Rangpur			246.4	216.7	463	54.9	518
Dinajpur				91.0	91	12.5	104
Rajshahi		103.7		106.2	210	198.5	408
Southwest							
Faridpur	14	319.6		181.7	515	28.8	544
Patuakhali				1,074.4	1,074		1,074
Barisal	224			1,537.1	1,761	0.8	1,762
Khulna				2,236.1	2,236	7.0	2,243
Jessore		51.2		174.8	226	77.7	304
Kushtia				61.9	62	36.6	99
Total	740	694.9	736.7	8,344.1	10,316	1,884.5	12,200

Source: Water Area Statistics of Bangladesh, Fisheries Information Bulletin Vol. 2 (1), 1986. DOF.

Table 34

Number of Fishing Units and Fishing Boats Operating in Different Riverine Waters of Bangladesh

Items	Meghna (River 1)	Padma (River 2)	J-B.putra (River 3)	Others (River 4)	Total
Fishing Units[a]					
Dry Season	10,117	2,228	1,989	17,006	31,340
(%)	32	7	6	54	100
Wet Season	15,722	2,922	1,728	19,283	39,655
(%)	40	7	4	49	100
Average	12,920	2,575	1,859	18,145	35,498
(%)	36	7	5	51	100
Fishing Boats[b]	24,641	9,049	3,065	N.A.	36,755
(%)	67	25	8	N.A.	100

a: estimated based on monthly sample survey of operating fishing units by BFRSS/DOF, Bangladesh for the period 1985-86 and 1986-87.
b: survey of fishing vilages and fishing boats by DOF.

Table 35

Distribution of Sample Fishing Units in the Selected Areas of Riverine Fishing in Bangladesh

River Group	River	District	No. of Samples	Sample as % of boats[a]
Riv 1:	Lower Meghna	Comilla	50	
		Barisal	60	
	Upper Meghna	Dhaka	15	
		Comilla	40	
	sub-total:		165	4.15
Riv 2:	Lower Padma	Faridpur	30	
		Dhaka	20	
	Upper Padma	Rajshahi	25	
	sub-total:		75	4.12
Riv 3:	Jamuna-B.putra	Pabna	20	
		Rangpur	55	
	sub-total:		75	13.11
Riv 4:	Garai-Madumati	Faridpur	30	
	Old Brahmaputra	Mymensingh	30	
	Tetulia	Barisal	40	
	sub-total:		100	
ALL	Total:		415	

a: according to survey of fishing boats by DOF (unpub).

Table 36

Distribution of Sample by River and Species in Each Season

Species	Meghna (Riv.1)	Padma (Riv.2)	J-B.Putra (Riv.3)	Others (Riv.4)	Total
Hilsa:					
-wet season	105	32	28	45	210
-dry season	73	20	17	15	125
Prawn:					
-wet season	5	5	6	9	25
-dry season	6	7	8	9	30
Catfish:					
-wet season	15	14	20	13	62
-dry season	24	20	18	25	87
Carp:					
-wet season	10	13	12	15	50
-dry season	22	16	18	24	80
Miscellaneous:					
-wet season	30	11	9	18	68
-dry season	40	12	14	27	93
All					
-wet season	165	75	75	100	415
-dry season	165	75	75	100	415

Table 37

Computed Average Cost of Catch (AC) Equations for Representative Fishing Units in Different Rivers of Bangladesh by Species and Season

Species	Season	Average Cost (AC)	Effort[a] Mean	Effort[a] S.D.	Catch[b] Mean	Catch[b] S.D.
Prawn:						
-River 1	dry	AC=64.74+.015q	1.13	0.80	726	826
	wet	AC=73.80+.017q	1.58	1.30	534	700
-River 2	dry	AC=70.33+.017q	2.20	1.20	1,054	1,120
	wet	AC=80.99+.017q	4.35	2.50	1,115	900
-River 3	dry	AC=10.38+.017q	3.38	1.75	2,854	2,000
	wet	AC=24.17+.0017q	1.54	0.60	648	500
-River 4	dry	AC=30.36+.017q	0.72	0.29	405	450
	wet	AC=26.36+.017q	0.90	0.30	353	340
Catfish:						
-River 1	dry	AC=14.29+.00145q	1.60	1.20	2,131	1,800
	wet	AC=26.55+.0009q	2.90	1.59	1,395	1,200
-River 2	dry	AC=30.36+.145q	5.62	2.31	358	384
	wet	AC=28.36+.0009q	1.23	1.41	554	600
-River 3	dry	AC=23.74+.00145q	6.31	2.29	4,616	3,540
	wet	AC=28.98+.0009q	1.68	1.29	725	680
-River 4	dry	AC=10.91+.00145q	2.48	1.17	3,147	2,780
	wet	AC= 8.91+.0009q	2.27	2.10	3,671	3,542
Carp:						
-River 1	dry	AC=17.66+.0062q	2.69	1.20	1,630	1,340
	wet	AC=28.00+.0009q	4.84	2.60	1,267	1,123
-River 2	dry	AC=22.43+.0062q	0.80	0.28	265	223
	wet	AC=18.43+.0009q	1.38	0.51	307	331
-River 3	dry	AC= 5.88+.0062q	2.00	1.30	703	697
	wet	AC=11.44+.0009g	0.58	0.40	342	361
-River 4	dry	AC=28.20+.0062q	2.70	1.80	1,339	1,145
	wet	AC=16.20+.0009q	3.34	3.20	2,935	2,410
Miscl:						
-River 1	dry	AC=12.78+.00315q	3.78	1.68	2,089	1,230
	wet	AC=16.69+.0017q	12.65	8.32	4,704	1,580
-River 2	dry	AC= 9.25+.00315q	4.19	0.89	3,187	1,421
	wet	AC= 9.63+.0017q	7.76	4.22	5,327	3,221
-River 3	dry	AC= 6.78+.00315q	10.43	5.88	5,762	3,124
	wet	AC= 5.28+.0017q	9.17	4.19	5,343	4,342
-River 4	dry	AC= 2.83+.00315q	2.27	3.49	2,635	1,978
	wet	AC= 2.62+.0017q	2.32	4.59	3,186	2,789

Source: Based on estimated regression equations for sample fishing units.

a: gear hours x 10^6

b: amount in kg.

Table 38

Aggregate Average Cost of Catch (AC) Equations for Various Fisheries in the Rivers of Bangladesh

Species	River	Season	AC Equations
Hilsa	River 1	dry	AC = 11.62 + .00029Q
		wet	AC = 7.19 + .00021Q
	River 2	dry	AC = 18.87 + .00285Q
		wet	AC = 5.08 + .00312Q
	River 3	dry	AC = 25.05 + .00225Q
		wet	AC = 30.85 + .0035Q
	River 4	dry	AC = 3.14 + .00057Q
		wet	AC = 8.78 + .00029Q
Prawn	River 1	dry	AC = 64.74 + .009Q
		wet	AC = 73.80 + .0048Q
	River 2	dry	AC = 70.33 + .14Q
		wet	AC = 80.99 + .1492Q
	River 3	dry	AC = 10.38 + .245Q
		wet	AC = 24.17 + .0557Q
	River 4	dry	AC = 30.36 + .000956Q
		wet	AC = 26.36 + .000556Q
Catfish	River 1	dry	AC = 14.29 + .00357Q
		wet	AC = 26.55 + .00247Q
	River 2	dry	AC = 30.36 + .009Q
		wet	AC = 28.36 + .007Q
	River 3	dry	AC = 23.74 + .01187Q
		wet	AC = 28.98 + .00197Q
	River 4	dry	AC = 10.91 + .001485Q
		wet	AC = 8.91 + .001485Q
Carp	River 1	dry	AC = 17.66 + .0204Q
		wet	AC = 28.00 + .008Q
	River 2	dry	AC = 22.43 + .0159Q
		wet	AC = 18.43 + .00596Q
	River 3	dry	AC = 5.88 + .011Q
		wet	AC = 11.44 + .00158Q
	River 4	dry	AC = 28.20 + .002478Q
		wet	AC = 16.20 + .001Q
Miscl.	River 1	dry	AC = 12.78 + .00102Q
		wet	AC = 16.69 + .00129Q
	River 2	dry	AC = 9.25 + .006Q
		wet	AC = 9.63 + .0052Q
	River 3	dry	AC = 6.78 + .00576Q
		wet	AC = 5.28 + .0030Q
	River 4	dry	AC = 2.83 + .000332Q
		wet	AC = 2.62 + .0002Q

Source: computed at the average catch per annum and based on sample AC equations in Table 37.
Note: Q = total catch ('000 kg) AC = average cost/kg.

Table 39

Monthly Market Margin Equations for Various Species
Landed from Rivers of Bangladesh
by Region and Season

Species	Region	Season	Equation
Hilsa:			
	Region A:	Dry	MM1.1.1= 5.73-0.01539Q1.1.1
	Region A:	Wet	MM1.1.2= 3.48-0.00085Q1.1.2
	Region B:	All	MM1.2 = 6.98-0.00003Q1.2
	Region C:	All	MM1.3 = 4.74-0.0076Q1.3
Small Prawn:			
	Region A:	Dry	MM4.1.1=16.00-0.0030Q4.1.1
	Region A:	Wet	MM4.1.2=18.54+0.00125Q4.1.2
	Region B:	All	MM4.2 =21.34+0.0033Q4.2
	Region C:	All	MM4.3 =18.97+0.032Q4.3
Big Prawn:			
	National:	All	MM8.0 =22.00+0.037Q8.0
Carp:			
	Region A:	Dry	MM2.1.1=20.44-0.0104Q2.1.1
	Region A:	Wet	MM2.1.2=16.68-0.0133Q2.1.2
	Region B:	All	MM2.2 =19.60-0.061Q2.2
	Region C:	All	MM2.3 =14.26+0.0022Q2.3
Catfish:			
	Region A:	All	MM3.1 = 8.04+0.002Q3.1
	Region B:	Dry	MM3.2.1= 2.57+0.0063Q3.2.1
	Region B:	Wet	MM3.2.2= 7.17+0.0063Q3.2.2
	Region C:	All	MM3.3 = 1.58+0.0106Q3.3
Miscellaneous:			
	Region A:	All	MM5.1 = 7.72+0.0017Q5.1
	Region B:	Dry	MM5.2.1=11.75+00034Q5.2.1
	Region B:	Wet	MM5.2.2= 9.63+0.00034Q5.2.2
	Region C:	All	MM5.3 = 7.22+0.0030Q5.3

Source: Derived as the difference between retail and ex-vessel prices shown in Tables 11 and 12 (Chapter V).

Note: Q = quantity in thousand kg.

Table 40

Annual Retail Demand Equations for Various Species of Fish Harvested from the Riverine Waters of Bangladesh

Species	Equations
Hilsa:	P = 26.59 - 0.000017Q
Prawn (small)	P = 49.47 - 0.00011Q
Catfish:	P = 29.39 - 0.00003Q
Carp:	P = 52.54 - 0.00057Q
Miscellaneous:	P = 29.25 - 0.000008Q

Source: aggregated from monthly retail demand equation in Table 11, Chapter Five.

Note: P = price/kg (BDT), Q = quantity of fish (thousand kg).

Table 41

Average Cost Per Unit of Effort for Various Fisheries in Each Season in the Rivers of Bangladesh (amount in BDT)

	Cost Per Unit of Effort[a]			
Species	Wet Season	Sample Size	Dry Season	Sample Size
Hilsa	8,154 (10,202)[b]	210	10,245 (18,559)	125
Prawn	26,492 (8,656)	25	43,095 (90,860)	30
Catfish	13,076 (8,341)	62	22,281 (24,530)	87
Carp	7,364 (5,626)	50	16,292 (12,382)	80
Miscl.	10,500 (14,936)	68	12,200 (12,936)	93

Source: Field survey (1987-88).

a: Effort unit is measured in gear hours x 10^6.
b: Figures in the parentheses indicate standard deviation.

Table 42

Percentage of By-Catch to Direct Catch from Various Fisheries in Different Rivers of Bangladesh in Each Season

Species of By-catch	Hilsa		Prawn		Catfish		Carp		Miscl.	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
River 1										
Hilsa	-	-	50	10	50	10	50	10	50	25
Prawn	0	0	-	-	5	5	5	3	5	3
Catfish	0	0	2	2	-	-	10	5	0	3
Carp	0	0	1	2	10	3	-	-	0	2
Miscl.	4	20	40	50	50	50	50	50	-	-
River 2										
Hilsa	-	-	5	5	10	10	10	10	10	10
Prawn	0	0	-	-	5	5	10	10	5	5
Catfish	1	1	1	1	-	-	5	5	1	1
Carp	1	1	1	1	2.5	2.5	-	-	1	1
Miscl.	25	25	20	20	50	50	50	50	-	-
River 3										
Hilsa	-	-	2	2	2	2	1	2	0.2	2.5
Prawn	0	0	-	-	5	5	5	5	1	2
Catfish	1	1	5	5	-	-	5	5	2	2
Carp	1	1	5	5	5	5	-	-	1	2
Miscl.	50	50	50	50	50	50	50	50	-	-
River 4										
Hilsa	-	-	5	5	5	5	5	5	10	10
Prawn	0	0	-	-	5	5	5	5	10	10
Catfish	0	0	2	2	-	-	5	5	1	1
Carp	0	0	2	2	5	5	-	-	1	1
Miscl.	30	30	30	30	50	50	30	30	-	-

Species of Direct Catch (column groups Hilsa to Miscl.)

Source: Field Survey, 1987-88.

Table 43

Percentage Distribution of Harvest of Various Species from Each River to Different Regions of Bangladesh in Each Fishing Season

	Wet Season				Dry Season			
Species	Reg.A	Reg.B	Reg.C	Total	Reg.A	Reg.B	Reg.C	Total
Hilsa:								
-River 1	9	91	0	100	2	98	0	100
-River 2	0	84	16	100	0	78	22	100
-River 3	0	0	100	100	0	0	100	100
-River 4	43	51	6	100	43	49	8	100
Prawn:								
-River 1	68	32	0	100	35	65	0	100
-River 2	0	40	60	100	0	54	40	94
-River 3	0	0	1	100	0	0	1	1
-River 4	73	26	1	100	47	52.5	0.5	100
Catfish:								
-River 1	4	96	0	100	27	73	0	100
-River 2	0	66	34	100	0	28	72	100
-River 3	0	0	100	100	0	0	100	100
-River 4	58	35	6	99	73	19	8	100
Carp:								
-River 1	49	51	0	100	69	31	0	100
-River 2	0	12	88	100	0	12	0	100
-River 3	0	0	100	100	0	0	100	100
-River 4	58	35	6	99	91	4	5	100
Miscl.:								
-River 1	41	51	0	100	56	44	0	100
-River 2	0	30	70	100	0	35	65	100
-River 3	0	0	100	100	0	0	100	100
-River 4	70	24	6	100	66	27	7	100

Source: Based on Fish Catch Statistics by species, district and river group (1983-84 - 1986-87), DOF/BFRSS (unpublished).

Table 47

Average Size of Fishing Gear (Net) Per Fishing Unit for Various Fisheries in the Rivers of Bangladesh (sq m)

Species	River 1	River 2	River 3	River 4	All
Hilsa:					
-wet season	6,891	4,644	2,768	5,629	4,983
-dry season	6,319	5,215	1,192	5,707	4,608
Prawn:					
-wet season	660	1,816	643	376	874
-dry season	615	1,156	1,776	378	981
Catfish:					
-wet season	1,133	961	656	887	909
-dry season	784	2,755	3,093	1,216	1,962
Carp:					
-wet season	1,999	570	479	1,380	1,107
-dry season	1,359	404	1,010	1,364	1,034
Miscl.:					
-wet season	5,136	3,151	5,327	942	3,639
-dry season	1,809	2,106	5,241	1,141	2,597

Source: Field survey (1987-88).

Table 48

Changes in Aggregate Effort (gear hours x 10^6) Availability in the Base Model for Riverine Fisheries of Bangladesh

	E = 20,000						E = 40,000					
Items	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Benefit	115.0	121.1	36.5	29.6	273.5	575.6	164.7	183.9	41.3	50.6	376.6	817.1
Gross Benefit	216.3	364 0	104.0	70.5	540.3	1,295.1	324.7	680.3	177.5	97.8	857.9	2,138.2
Producer Surplus (P.S)	102.9	119.8	36.3	29.1	272.2	560.3	164.2	179.4	40.7	49.8	373.1	807.2
Consumer Surplus (C.S.)	12.1	1.2	0.2	0.5	1.3	15.3	0.5	4.5	0.6	0.9	3.6	10.0
Total Revenue	204.1	362.8	103.9	70.0	539.0	1,279.8	324.2	675.8	177.0	96.9	854.3	2,128.3
Total Cost	101.3	243.0	67.6	40.9	266.8	719.5	160.0	496.4	136.2	47.2	481.3	1,321.1
-Harvest	51.3	131.3	43.1	12.0	88.1	325.7	80.3	279.0	95.1	14.7	181.4	653.6
-Post-harvest	50.0	111.7	24.4	28.9	170.7	393.7	79.7	217.4	41.1	29.4	299.9	667.5
Catch-Effort												
Total catch (mt)	7,715	5,573	3,547	1,353	18,521	36,709	12,291	10,483	6,059	1,883	29,450	60,166
-direct catch	6,000	4,120	3,200	910	14,150	28,380	9,294	8,160	5,520	1,134	21,596	45,704
-by-catch	1,715	1,453	647	443	4,371	8,329	2,997	2,323	539	749	7,854	14,462
Total effort[b]	5,570	3,763	2,405	988	7,274	20,000	9,130	8,003	5,531	1,364	15,982	40,000
Catch/Effort[c] (kg/gear hour x 10^6)	1,077	1,095	1,331	921	1,945	1,835	1,018	1,020	998	838	1,351	1,504
Price and Unit Cost (BDT/kg)												
Price[a]	26.46	48.94	29.28	51.77	29.1		26.38	48.45	29.21	51.47	29.01	
Harvest Cost	6.65	23.55	12.15	8.86	4.75	8.87	6.53	26.62	15.7	9.42	6.16	10.86
Post-Harvest Cost	6.48	20.04	6.89	21.37	9.65	10.73	6.49	20.74	6.78	15.63	10.18	11.09

Table 49

Behaviour of Different Fisheries in the Rivers of Bangladesh
Under Alternative Cost Conditions
(Changes in the Cost of Harvesting from the Base Model)

	BASE MODEL						25% increase					
Items	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Benefit	497.7	246.7	49.5	80.4	508.8	1,383.2	280.3	154.9	7.7	51.1	434.5	928.5
Gross benefit	2,025.4	1,219.5	271.2	359.1	1,758.8	5,634.1	1,509.0	747.5	248.3	277.2	,370.6	4,152.5
Producer Surplus (P.S.)	446.6	234.0	48.5	66.2	493.7	1,288.9	249.2	149.5	6.7	42.9	425.1	873.4
Consumer Surplus (C.S.)	51.1	12.8	1.1	14.2	15.2	94.3	31.0	5.5	1.0	8.3	9.4	55.1
Total Revenue	1,974.3	1,206.8	270.2	344.9	1,743.6	5,539.8	1,478.0	742.1	247.3	268.9	1,361.2	4,097.4
Total Cost	1,527.8	972.8	221.7	278.7	1,250.0	4,250.9	1,228.7	592.6	240.6	226.0	936.1	3,224.0
-Harvest	1,017.5	574.7	159.6	161.2	522.1	2,435.2	851.2	350.3	182.9	136.8	407.5	1,928.7
-Post-harvest	510.3	398.0	62.1	117.5	727.9	1,815.7	377.5	242.2	57.7	89.3	528.6	1,295.3
Catch-Effort												
Total Catch (mt)	78,161	17,981	9,281	7,113	60,627	173,163	57,710	11,440	8,486	5,439	47,150	130,225
-direct catch	70,350	13,850	7,960	5,741	41,956	139,857	52,560	8,200	7,520	4,588	31,800	104,668
-by-catch	7,811	4,131	1,321	1,372	18,671	33,306	5,150	3,240	966	851	15,350	25,557
Total Effort[b]	111,321	16,804	9,336	13,654	45,939	197,054	77,045	8,050	8,436	9,294	28,668	131,493
Catch/Effort[c] (kg/gear hour x 10^6)	632	824	853	421	913	879	682	1,019	891	494	1,109	990
Price and Unit Cost (BDT/Kg)												
Price[d]	25.26	47.79	29.11	48.49	28.76		25.61	48.37	29.14	49.44	28.87	
Harvest Cost	13.02	31.96	17.20	22.67	8.61	14.06	14.75	30.62	21.55	25.15	8.64	8.87
Post-harvest Cost	6.53	22.14	6.69	15.51	12.01	10.49	6.54	21.17	6.80	16.41	11.21	10.73

Table 49 (continued ...)

Items	50% increase						25% decrease					
	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
<u>Benefit-Cost</u>[a]												
Net Benefit	197.6	126.7	0.8	37.6	278.9	641.6	808.8	416.9	96.1	127.2	809.1	2,258.0
Gross ben.	1,040.7	470.7	176.5	184.5	1,168.6	3,041.0	2,648.1	1,956.5	312.9	519.6	2,661.8	8,098.9
P.S.	184.4	124.8	0.4	34.1	272.6	616.3	719.2	385.2	94.8	97.0	357.0	1,653.2
C.S.	13.1	1.8	0.4	3.6	6.3	25.3	89.6	31.6	1.3	30.2	452.1	604.8
T. Rev.	1,027.5	468.8	176.1	180.9	1,162.3	3,015.7	2,558.5	1,924.8	311.6	489.4	2,209.8	7,494.1
T. Cost	843.1	344.0	175.7	146.9	889.7	2,399.4	1,839.3	1,539.6	216.8	392.4	1,852.7	5,840.9
-Harvest	583.7	197.9	135.2	88.9	450.8	1,456.5	1,174.1	854.8	145.2	222.5	521.8	2,918.5
-Post-harvest	259.5	146.1	40.5	58.0	438.9	943.0	665.2	684.8	71.6	169.9	1,331.0	2,922.5
<u>Catch-Effort</u>												
T. Catch(mt)	39,642	7,152	6,024	3,583	40,177	96,578	103,000	28,648	10,718	10,514	77184	230,064
-direct catch	35,000	4,146	5,320	2,758	30,139	77,363	92,483	23,670	8,850	8,757	50500	184,260
-by-catch	4,642	3,006	704	825	10,038	19,215	10,517	4,978	1,868	1,757	26,684	45,804
Total Effort[b]	43,938	3,789	5,306	5,179	26,459	84,671	173,194	33,931	11,069	23,514	61,393	303,101
Catch/Effort[c]	797	1,094	1,003	533	1,139	1,141	534	698	800	372	823	759
<u>Price and Unit Cost</u>(DDT/Kg)												
Price[d]	25.92	48.79	29.23	50.50	28.93		24.84	46.81	29.07	46.55	28.63	
Harvest Cost	14.72	27.67	22.45	24.80	11.22	15.08	11.40	29.84	13.55	21.17	6.76	12.69
Post-har. Cost	6.54	20.42	6.72	16.20	10.92	9.76	6.46	23.90	6.68	16.16	17.24	12.70

Table 49 (continued ...)

Items	Hilsa	Prawn	Catfish	Carp	Miscl.	All
			50% decrease			
Benefit-Cost[a]						
Net Ben.	1,075.9	906.9	158.1	263.1	404.0	2,808.1
Gross ben.	3,383.0	3,060.9	363.1	755.1	3,150.0	10,712.1
P.S.	925.7	823.0	155.8	192.7	65.7	2,162.9
C.S.	150.2	83.9	2.3	70.4	338.3	645.1
T. Rev.	3,232.7	2,977.0	360.8	684.7	2,811.7	10,066.9
T. Cost	2,307.0	2,154.0	205.0	492.0	2,746.0	7,904.0
-Harvest	1,257.0	970.0	112.0	242.0	605.0	3,186.0
-Post-harv.	1,050.0	1,184.0	93.0	250.0	2,141.0	4,718.0
Catch-Effort						
T. Catch	132,870	45,837	12,433	15,711	98795	305,646
-dir. catch	118,255	38,962	10,071	13,355	65229	245,872
-by-catch	14,615	6,875	2,362	2,356	33,566	59,774
T. Effort[b]	275,011	66,037	13,609	41,734	86,972	483,363
Catch/Effort[c] (kg/gear hour x 10^6)	430	590	740	320	750	632
Price and Unit Cost (BDT/Kg)						
Price[d]	24.33	45.18	29.02	43.58	28.46	
Harvest Cost	9.46	21.16	9.01	15.40	6.12	10.42
Post-har. Cost	7.90	25.83	7.48	15.91	21.67	15.44

a: million Bangladesh Taka (BDT)
b: gear hours x 10^6.
c: ratio of direct catch to total effort.
d: in the case of prawn practice indicates that of only small prawns, price of big prawn is fixed at BDT177/kg.

Table 50

Changes in the Availability of Effort (gear hours x 10^6) for a 25% Increase in the Cost of Harvest from the Base Model for Riverine Fisheries of Bangladesh

	E = 20,000						E = 40,000					
Items	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Benefit	89.6	85.2	25.8	34.9	260.4	495.8	182.9	123.1	20.1	42.2	306.9	675.3
Gross benefit	203.5	328.6	104.1	71.8	552.8	1,260.8	452.4	415.7	159.7	87.3	807.0	1,922.1
Producer Surplus	89.3	84.3	25.6	34.4	250.9	490.6	180.8	121.5	19.7	41.5	303.2	665.9
Consumer Surplus	0.3	0.9	0.2	0.5	1.5	5.2	2.1	1.6	0.4	0.8	3.8	9.4
Total Revenue	203.2	327.7	103.9	71.3	551.3	1,255.6	450.3	414.1	159.3	86.6	803.3	1,912.7
Total Cost	113.9	243.4	78.3	36.9	292.4	765.0	269.4	292.6	139.6	45.1	500.1	1,246.8
-Harvest	64.1	142.3	53.9	15.9	110.1	386.3	158.1	164.1	101.7	19.1	220.0	663.0
-Post-harvest	49.8	101.2	24.4	21.1	182.3	378.7	111.4	128.5	37.8	26.0	280.1	583.8
Catch-Effort												
Total Catch(mt)	7,691	5,023	3,549	1,378	18,952	36,593	17,121	6,362	5,449	1,678	27,670	58,280
-direct catch	6,000	3,561	3,200	940	13,900	27,601	14,500	4,120	5,000	1,047	21,156	45,823
-by-catch	1,691	1,462	349	438	5,052	8,992	2,621	2,242	449	631	6,514	12,457
Total Effort[b]	5,570	3,261	2,405	1,049	7,715	20,000	14,791	3,763	4,733	1,208	15,505	40,000
Catch/Effort[c]	1,077	1,092	1,331	896	1,802	1,830	980	1,095	1,056	867	1,364	1,457
Shadow Price						14.48						8.41
Price and Unit Cost (BDT/Kg)												
Price[c]	26.42	48.99	29.28	51.75	29.09		26.30	48.86	29.23	51.58	29.03	
Harvest Cost	8.34	28.33	15.18	11.52	5.31	10.56	9.23	25.80	18.67	11.36	7.95	11.38
Post-harvest Cost	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53

Table 50 (continued ...)

Items	E = 80,000						E = 120,000					
	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Ben.	273.8	146.6	22.9	56.7	370.1	869.9	294.1	158.4	9.7	51.1	413.3	926.5
Gross ben.	894.7	727.9	184.6	184.4	1,196.2	3,187.8	1,361.9	745.0	247.0	270.5	1,330.3	3,954.0
P.S.	263.7	141.4	22.3	53.1	363.4	843.9	271.5	153.0	8.7	43.3	407.6	884.0
C.S.	10.0	5.2	0.6	3.5	6.7	26.1	22.6	5.4	1.0	7.9	5.6	42.5
T. Rev.	884.7	722.7	184.0	180.9	1,189.5	3,161.8	1,339.3	739.6	246.0	262.6	1,324.7	3,912.1
T. Cost	621.0	581.3	161.8	127.8	826.1	2,317.9	1,067.8	586.6	237.3	219.3	917.0	3,028.1
-Harvest	398.2	348.8	118.9	69.7	374.2	1,309.8	726.5	348.8	180.0	132.3	407.5	3,020.1
-Post-harvest	222.0	232.6	42.9	58.0	451.9	1,008.1	341.3	237.9	57.4	87.0	509.5	1,233.0
Catch-Effort												
T. Catch	34,014	11,169	6,302	3582	41,130	96,197	52,112	11,397	8,442	5,303	45,868	123,122
-dir. catch	29,228	8,160	5,520	2,673	30,059	75,640	46,978	8,160	7,520	4,251	31,800	98,709
-by-catch	4,786	3,009	782	909	11,071	20,557	5,134	3,237	922	1,052	14,068	24,413
T. Effort[b]	35,280	8,003	5,531	4,816	26,370	80,000	65,816	8,003	8,436	9,077	28,668	120,000
Catch/Effort[c] (kg/gear hour x 10^6)	828	1,020	998	555	1,140	1,202	714	1,020	891	468	1,109	1,026
Shadow Price (BDT/gear hour x 10^3)						3.25						0.2
Price and Unit Cost (BDT/Kg)												
Price[d]	26.01	48.40	29.20	50.50	28.92		25.70	48.37	29.14	49.52	28.88	
Harvest Cost	11.71	31.23	18.87	19.47	9.10	13.62	13.94	30.60	21.32	24.96	8.88	24.59
Post-har. Cost	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53	6.53

Table 50 (continued ...)

Items	E = 160,000					
	Hilsa	Prawn	Catfish	Carp	Miscl.	All
<u>Benefit-Cost</u>[a]						
Net Ben.	280.3	154.9	7.7	51.1	434.4	928.5
Gross ben.	1,509.0	747.5	248.3	277.2	1,370.6	4,152.5
P.S.	249.2	149.5	6.7	42.9	425.1	873.4
C.S.	31.0	5.5	1.0	8.3	9.4	55.1
T. Rev.	1,478.0	742.1	247.3	268.9	1,361.2	4,097.4
T. Cost	1,228.7	592.6	240.6	226.0	936.1	3,224.0
-Harvest	851.2	350.3	182.9	136.8	407.5	1,928.7
-Post-harv.	377.5	242.2	57.7	89.3	528.6	1,295.3
<u>Catch-Effort</u>						
T. Catch	57,710	11,440	8,486	5,439	47,150	130,225
-dir. catch	52,560	8,200	7,520	4,588	31,800	104,668
-by-catch	5,150	3,240	966	851	15,350	25,557
T. Effort[b]	77,045	8,050	8,436	9,294	28,668	131,493
Catch/Effort[c] (kg/gear hour x 10^6)	682	1,019	891	494	1,109	990
Shadow Price (BDT/gear hour x 10^3)						0
<u>Price and Unit Cost</u> (BDT/Kg)						
Price[d]	25.61	48.37	29.14	49.44	28.87	
Harvest Cost	14.75	30.62	21.55	25.15	8.64	8.87
Post-har.Cost	6.54	21.17	6.80	16.41	11.21	10.73

a: million Bangladesh Taka (BDT).
b: gear hours x 10^6.
c: ratio of direct catch to total effort.
d: in the case of prawn practice indicates that of only small prawns, price of big prawn is fixed at BDT177/kg.

Table 51 (continued ...)

Items	E = 200,000						E = 303,101					
	Species						Species					
	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
<u>Benefit-Cost</u>[a]												
Net Benefit	748.26	454.22	90.46	131.74	700.92	2,126	808.77	416.86	96.08	127.16	809.10	2,258
Gross benefit	1,824.16	1,688.77	300.07	377.99	2,469.74	6,661	2,648.11	1,956.46	312.88	519.60	2,661.84	8,099
P.S	707.26	431.34	89.19	115.70	287.25	1,631	719.18	385.23	94.77	96.99	357.04	1,653
C.S.	41.00	22.88	1.27	16.04	413.67	495	89.59	31.63	1.31	30.17	452.06	605
Total Revenue	1,783.16	1,665.89	298.80	361.95	2,056.07	6,166	2,558.52	1,924.83	311.57	489.43	2,209.78	7,494
Total Cost	1,075.90	1,234.55	209.61	246.25	1,768.82	4,535	1,839.34	1,539.60	216.80	392.44	1,852.74	5,841
-Harvest	618.13	687.79	141.33	125.61	533.08	2,106	1,174.13	854.81	145.21	222.53	521.79	2,919
-Post-harvest	457.77	546.76	68.28	120.64	1,235.74	2,430	665.21	684.79	71.59	169.91	1,330.95	2,923
<u>Catch-Effort</u>												
Total Catch (mt)	70,203	24,424	10,275	7,500	71,690	184,092	103,000	28,648	10,718	10,514	77,184	230,064
-direct catch	59,669	19,610	8,730	5,914	50,600	144,523	92,483	23,670	8,850	8,757	50,500	184,260
-by-catch	10,534	4,814	1,545	1,586	21,090	39,569	10,517	4,978	1,868	1,757	26,684	45,804
Total Effort[b] (hr)	87,558	27,355	10,837	12,419	61,831	200,000	173,194	33,931	11,069	23,514	61,393	303,101
Catch/Effort[c] (Kg)	681	717	806	476	818	920	534	698	800	372	823	759
Shadow Price						2.72						0
<u>Price and Unit Cost</u>(BDT/Kg)												
Price[d]	25.40	47.22	29.08	48.26	28.68		24.84	46.81	29.07	46.55	28.63	
Harvest Cost	8.80	28.16	13.75	16.75	7.44	11.44	11.40	29.84	13.55	21.17	6.76	12.69
Post-harvest Cost	6.52	22.39	6.65	16.09	17.24	13.20	6.46	23.90	6.68	16.16	17.24	12.70

a: million BDT; b: gear hours x 10^6; c: ratio of direct catch (in kg) to total effort;
d: as for prawn price indicates that of only small prawns; price of big prawn is fixed at BDT177/kg.

Table 52

Behaviour of Different Fisheries in the Rivers of Bangladesh
under Alternative Demand Conditions
(Changes in the demand intercept from the BASE MODEL)

Items	BASE MODEL						10% increase					
	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Benefit	497.65	246.73	49.54	80.42	508.83	1,383.17	773.20	340.33	77.19	121.47	787.05	2,099.24
Gross benefit	2,025.40	1,219.51	271.24	359.11	1,758.81	5,634.07	2,452.00	1,713.91	334.97	494.40	2,941.13	7,936.41
Producer Surplus (P.S.)	446.60	233.98	48.47	66.22	493.65	1,288.92	711.78	318.42	75.64	99.82	290.41	1,496.08
Consumer Surplus (C.S.)	51.05	12.75	1.07	14.20	15.18	94.25	61.42	21.91	1.55	21.65	496.64	603.16
Total Revenue	1,974.35	1,206.76	270.17	344.91	1,743.63	5,539.82	2,390.58	1,692.00	333.42	472.75	2,444.49	7,333.25
Total Cost	1,527.75	972.78	221.70	278.69	1,249.98	4,250.90	1,678.80	1,373.58	257.78	372.93	2,154.00	5,837.17
-Harvest	1,017.47	574.74	159.61	161.22	522.13	2,435.17	1,123.17	826.45	180.44	228.20	819.20	3,185.46
-Post-harvest	510.28	398.04	62.09	117.47	727.85	1,815.73	555.63	547.13	69.34	144.73	1,334.88	2,651.71
Catch-Effort												
Total Catch (mt)	78,161	17,981	9,281	7,113	60,627	173,163	86,023	23,720	10413	8,974	77,480	206,610
-direct catch	70,350	13,850	7,960	5,741	41,956	139,857	74,900	18,560	8,730	7,333	55,324	164,847
-by-catch	7,811	4,131	1,321	1,372	18,671	33,306	11,123	5,160	1,683	1,641	22,156	41,753
Total Effort[b]	111,321	16,804	9,336	13,654	45,939	197,054	122,932	24,205	10,837	17,723	72,298	247,995
Catch/Effort[c] (kg/gear hour x 10^6)	632	824	853	421	913	879	609	767	806	414	765	833
Price and Unit Cost (BDT/Kg)												
Price[d]	25.26	47.79	29.11	48.49	28.76		27.79	52.21	32.02	52.68	31.55	
Harvest Cost	13.02	31.96	17.20	22.67	8.61	14.06	13.06	34.84	18.10	25.43	10.57	15.42
Post-harvest Cost	6.53	22.14	6.69	16.51	12.01	10.49	6.46	23.07	6.66	16.13	17.23	12.83

Table 53

Changes in the Availability of Effort (gear hours x 10^6) for a 10% Decrease in the Aggregate Demand from the Base Model for Riverine Fisheries of Bangladesh

	E = 20,000						E = 40,000					
Items	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Benefit	04.31	97.87	26.57	30.46	228.85	467.56	117.5	150.47	24.40	40.52	294.81	627.7
Gross Benefit	102.90	341.72	94.29	101.10	492.19	1,212.20	237.0	653.53	160.96	116.45	851.26	2,019.2
Producer Surplus (P.S.)	83.93	96.61	26.34	29.29	226.08	463.15	117.1	145.72	23.82	38.86	290.47	615.9
Consumer Surplus (C.S.)	0.38	1.26	0.23	1.17	1.37	4.41	0.5	4.75	0.58	1.66	4.34	11.8
Total Revenue	182.52	340.46	94.06	99.93	490.82	1,207.79	236.5	648.78	160.38	114.79	846.92	2,007.4
Total Cost	98.59	243.85	67.72	70.64	263.84	744.64	119.4	503.06	136.56	75.93	556.45	1,391.4
-Harvest	49.30	131.27	43.11	37.01	02.34	343.03	55.6	279.03	95.14	36.92	216.61	683.3
-Post-harvest	49.29	112.58	24.61	33.63	101.50	401.61	63.9	224.03	41.42	39.01	339.84	708.2
Catch-Effort												
T. Catch (mt)	7,669	5,595	3,571	2,170	18,755	37,760	9,958	10,789	6,105	2,503	32,499	61,054
-direct catch	5,766	4,120	3,200	1,730	13,210	28,026	6,500	8,160	5,520	1,726	24,461	46,367
-by-catch	1,903	1,475	371	440	5,545	9,734	3,458	2,629	585	777	8,038	15,487
T. Effort(hr)[b]	5,383	3,763	2,405	1,296	7,183	20,000	6,091	8,003	5,531	1,289	19,086	40,000
Catch/Effort[c] (kg/gear hour x 10^6)	1,077	1,095	1,331	1,335	1,839	1,888	1,067	1,020	998	1,339	1,282	1.546
Shadow Price (BDT/gear hour x 10^3)						14.8						6.08
Price and Unit Cost(BDT/Kg)												
Price[d]	23.80	43.98	26.34	46.05	26.17		23.75	43.48	26.27	45.86	26.06	
Harvest Cost	6.43	23.46	12.07	17.06	4.39	9.08	5.58	25.86	15.58	14.75	6.67	11.05
Post-harvest Cost	6.43	20.12	6.89	15.50	9.68	10.64	6.41	20.76	6.78	15.59	10.46	11.45

Table 53 (continued ...)

Items	E = 30,000						E = 120,000					
	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Benefit	263.70	161.95	25.34	49.00	341.44	841.4	312.89	171.92	16.85	49.50	370.33	921.9
Gross Benefit	843.15	694.67	173.18	185.57	994.44	2,891.0	1,212.14	788.15	230.18	255.49	1,211.33	3,697.3
P.S.	253.33	156.71	24.67	44.51	335.99	815.2	291.05	165.89	15.78	41.00	361.99	875.7
C.S.	10.37	5.24	0.67	4.49	5.45	26.2	21.84	6.03	1.07	8.50	8.34	45.8
Total Rev.	832.78	689.43	172.52	181.08	988.99	2,864.8	1,190.30	782.12	229.11	246.99	1,202.99	3,651.5
Total Cost	579.45	532.72	147.84	136.57	653.00	2,049.6	899.25	616.23	213.33	205.99	841.00	2,775.8
-Harvest	348.13	296.30	103.99	72.76	241.69	1,062.9	564.26	352.07	154.76	116.34	326.04	1,513.5
-Post-harvest	231.32	236.42	43.85	63.81	411.31	986.7	334.99	264.16	58.57	89.65	514.96	1,262.3
Catch-Effort												
T. Catch (mt)	35,711	11,328	6,572	4025	38,009	95,645	51,640	12,394	8,748	5,602	46,358	124,742
-direct catch	31,922	8,410	5,824	3,151	26,500	75,807	46,150	9,134	7,800	4,530	31,800	99,414
-by-catch	3,789	2,918	748	874	11,509	19,838	5,490	3,260	948	1,072	14,558	25,328
T. Effort[b]	39,929	8,404	6,030	4,341	21,296	80,000	64,119	10,183	8,963	8,067	28,668	120,000
Catch/Effort[c] (kg/gear hour x 10^6)	799	1,001	966	726	1,244	1,196	720	897	870	562	1,109	1,040
Shadow Price (BDT/gear hour x 10^3)						4.39						0.77
Price and Unit Cost (BDT/Kg)												
Price[d]	23.32	43.44	26.25	44.99	26.02		23.05	43.36	26.19	44.09	25.95	
Harvest Cost	9.75	26.16	15.82	18.08	6.36	11.11	10.93	28.41	17.69	20.77	7.03	12.13
Post-harv. Cost	6.48	20.87	6.67	15.85	10.82	10.32	6.49	21.31	6.70	16.00	11.11	10.12

Table 53 (continued ...)

Items	Hilsa	Prawn	Catfish	Carp	Miscl.	All
	E = 160,000					
Benefit-Cost[a]						
Net Benefit	323.57	173.96	17.62	54.42	365.92	935.5
Gross Benefit	1,400.75	838.05	237.25	255.85	1,414.25	4,146.2
P.S.	293.20	167.66	16.44	45.56	290.96	813.8
C.S.	30.37	6.30	1.18	8.86	74.96	121.7
T. Rev.	1,370.38	831.75	236.07	246.99	1,339.29	4,024.5
T. Cost	1,077.18	664.09	219.63	201.43	1,048.33	3,210.7
-Harvest	689.41	384.69	159.63	111.78	396.01	1,741.5
-Post-harv.	387.77	279.4	60.00	89.65	652.32	1,469.1
Catch-Effort						
T.Catch(mt)	59,816	12947	9,017	5602	51,690	139,072
-dir. catch	52,930	9560	7,960	4421	35,200	110,071
-by-catch	6,886	3,387	1,057	1,181	16,490	29,001
Total Effort[b] (hr)	77,825	11,411	9,336	8,775	34,831	142,178
Catch/Effort[c] (kg/gear hour x 10^6)	680	838	853	504	1,011	978
Shadow Price (BDT/gear hour x 10^3)						0
Price and Unit Cost (BDT/Kg.)						
Price[d]	22.91	43.32	26.18	44.09	25.91	
Harvest Cost	11.53	29.71	17.70	19.95	7.66	
Post-harvest Cost	6.48	21.58	6.65	16.00	12.62	12.52

a: million Bangladesh Taka (BDT).
b: gear hours x 10^6.
c: ratio of direct catch to total effort.
d: in the case of prawn price indicates that of only small prawns; price of big prawn is fixed at BDT177/kg.

Table 54

Changes in the Availability of Effort (gear hours x 10^6) for a 10% Increase in the Aggregate Demand from the Base Model for Riverine Fisheries of Bangladesh

	E = 20,000						E = 40,000					
Items	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Benefit	124.88	146.23	47.58	53.25	338.04	709.98	170.74	246.68	63.11	66.24	487.17	1,033.94
Gross Benefit	223.51	390.09	115.28	123.89	601.98	1,454.75	290.19	751.08	190.28	142.15	1,193.12	2,566.82
Producer Surplus (P.S.)	124.69	144.95	47.36	52.10	336.60	705.69	169.90	241.82	62.61	64.62	338.34	877.28
Consumer Surplus (C.S.)	0.19	1.28	0.22	1.15	1.44	4.29	0.84	4.86	0.50	1.62	148.83	156.66
Total Revenue	223.32	388.81	115.06	122.74	600.54	1,450.46	289.35	746.22	189.78	140.53	1,044.29	2,410.16
Total Cost	98.63	243.86	67.70	70.64	263.94	744.77	119.45	504.40	127.17	75.91	705.95	1,532.88
-Harvest	49.30	131.27	43.11	37.01	82.34	343.03	55.55	279.03	89.40	37.07	221.95	683.00
-Post-harvest	49.33	112.59	24.59	33.63	181.60	401.74	63.90	225.37	37.77	38.84	484.00	849.88
Catch-Effort												
Total Catch (mt)	7,669	5,595	3,571	2,170	18,755	37,760	9,950	10,856	5,903	2,493	32,726	61,928
-direct catch	5,766	4,120	3,200	1,730	13,210	28,026	6,500	8,160	5,320	1,733	24,785	46,498
-by-catch	1,903	1,475	371	440	5,545	9,734	3,450	2,696	583	760	7,941	15,430
Total Effort[b]	5,353	3,763	2,405	1,296	7,183	20,000	6,091	8,003	5,094	1,301	19,511	40,000
Catch/Effort[c] (kg/gear hour x 10^6)	1,077	1,095	1,331	1,335	1,839	1,888	1,067	1,020	1,044	1,332	1,270	1,548
Shadow Price (BDT/gear hour x 10^3)						22.58						14.67
Price and Unit Cost (BDT/Kg)												
Price[d]	29.12	53.88	32.22	56.56	32.02		29.08	53.37	32.15	56.37	31.91	
Harvest Cost	6.43	23.46	12.07	17.06	4.39	9.08	5.58	25.70	15.14	14.87	6.78	11.03
Post-harvest Cost	6.43	20.12	6.89	15.50	9.68	10.64	6.42	20.76	6.40	15.58	14.79	13.72

Table 54 (continued ...)

Items	E = 80,000 Hilsa	Prawn	Catfish	Carp	Miscl.	All	E = 120,000 Hilsa	Prawn	Catfish	Carp	Miscl.	All
Benefit-Cost[a]												
Net Ben.	425.26	267.07	64.98	95.72	583.83	1,436.86	556.55	285.32	70.69	114.04	684.67	1,711.27
Gross Ben.	947.15	805.79	265.22	234.08	1,301.19	3,553.43	1,428.25	1,191.45	291.13	321.63	1,564.67	4,797.13
P.S.	417.08	261.54	63.94	90.95	577.82	1,411.33	542.14	274.24	69.51	104.81	675.12	1,665.82
C.S.	8.18	5.53	1.04	4.77	6.01	25.53	14.41	11.08	1.18	9.23	9.55	45.45
T. Rev.	938.97	800.26	264.18	229.31	1,295.18	3,527.90	1,413.84	1,180.37	289.95	312.40	1,555.12	4,751.68
T. Cost	521.89	538.72	200.24	138.36	717.36	2,116.57	871.70	906.13	220.44	207.59	880.00	3,085.86
-Harvest	309.73	297.99	144.01	72.66	271.31	1,095.70	549.76	541.53	160.14	115.87	326.04	1,693.34
-Post-harv.	212.16	240.73	56.23	65.70	446.05	1,020.87	321.94	364.60	60.30	91.72	553.96	1,392.52
Catch-Effort												
T. Catch	32,728	11,509	8,235	4137	40,665	97,274	49,783	16,698	9,044	5,729	48,934	130,188
-dir. catch	28,361	8,461	7,440	3,144	28,500	75,906	43,872	15,520	7,964	4,516	31,800	103,672
-by-catch	4,367	3,048	795	993	12,165	21,368	5,911	1,178	1,080	1,213	17,134	26,516
T. Effort[b]	35,220	8,464	8,257	4,335	23,724	80,000	58,489	15,573	9,247	8,023	28,668	120,000
Catch/Effort[c] (kg/gear hour x 10^6)	805	1,000	901	725	1,201	1,216	750	997	861	563	1,109	1,085
Shadow Price (BDT/gear hour x 10^3)						9.6						4.55
Price and Unit Cost(BDT/Kg)												
Price[d]	28.69	53.32	32.08	55.43	31.85		28.40	52.84	32.06	54.53	31.78	
Harvest Cost	9.46	25.89	17.49	17.56	6.67	11.26	11.04	32.43	17.71	20.23	6.66	13.01
Post-har. Cost	6.48	20.92	6.83	15.88	10.97	10.49	6.47	21.83	6.67	16.01	11.32	10.70

Table 54 (continued ...)

Items	E = 160,000						E = 200,000					
	Hilsa	Prawn	Catfish	Carp	Miscl.	All	Hilsa	Prawn	Catfish	Carp	Miscl.	All
<u>Benefit-Cost</u>[a]												
Net Ben.	656.71	311.57	73.23	120.65	697.52	1,859.68	728.76	352.49	75.59	124.14	654.01	1,934.99
Gross ben.	1,795.70	1278.5	307.70	405.52	1,862.67	5,650.09	2,126.14	1352.48	321.81	410.21	2,208.36	6,419.00
P.S.	624.27	299.07	71.86	105.63	684.18	1,785.01	681.34	338.86	74.04	108.73	634.99	1,837.96
C.S.	32.44	12.50	1.37	15.02	13.34	74.67	47.42	13.63	1.55	15.41	19.02	97.03
T. Rev.	1,763.26	1266	306.33	390.50	1,849.33	5,575.42	2,078.72	1338.85	320.26	394.80	2,189.34	6,321.97
Total Cost	1,138.99	966.93	234.47	284.87	1,165.15	3,790.41	1,397.38	999.99	246.22	286.07	1,554.35	4,484.01
-Harvest	733.61	574.74	170.68	167.81	471.98	2,118.82	916.74	582.44	182.43	167.59	691.58	2,540.78
-Post-har.	405.38	392.19	63.79	117.06	693.17	1,671.59	480.64	417.55	63.79	118.48	862.77	1,943.23
<u>Catch-Effort</u>												
T. Catch	62,549	17730	9,561	7280	58,320	155,440	74,293	18720	10,002	7367	69,239	179,621
-dir. catch	54,390	13850	8,280	5940	39,270	121,730	65,033	13910	8,580	5897	50,273	143,693
-by-catch	8,159	3,880	1,281	1,340	19,050	33,710	9,260	4,810	1,422	1,470	18,966	35,928
T. Effort[b]	79,405	16,804	9,831	12,437	41,523	160,000	99,000	17,025	10,497	12,478	61,000	200,000
Catch/Effort[c] (kg/gear hour x 10^6)	685	824	842	478	946	972	657	817	817	473	824	898
Shadow Price (BDT/gear hour x 10^3)						2.98						1.43
<u>Price and Unit Cost</u>												
Price[d]	28.19	52.76	32.04	53.64	31.71		27.98	52.67	32.02	53.59	31.62	
Harvest Cost	11.73	32.42	17.85	23.05	8.09	13.63	12.34	31.11	18.24	22.75	9.99	14.15
Post-har. Cost	6.48	22.12	6.67	16.08	11.89	10.75	6.47	22.31	6.38	16.08	12.46	10.82

a: million BDT; b: gear hours x 10^6; c: ratio of direct catch (in kg) to total effort;
d: in the case of prawn price indicates that of only small prawns; price of big prawn is fixed at BDT177/kg.

9. What is the ex-vessel price per kg of the various species caught in the current season?

Code	Species	Price (Tk.)/kg
1	hilsa	|___|___|___|
2	carp	|___|___|___|
3	catfish	|___|___|___|
4	prawn	|___|___|___|
5	others	|___|___|___|

10. How many fishing boats do you operate this season?

|_____|

11. What is the nature of ownership of boats?

|_____|

1 = self owned
2 = share rented
3 = cash rented

12. If the boat(s) is self-owned/share rented what is the percentage share of catch for the boat?

|___|___| %

13. If the boat(s) is rented for cash what is the total rent for the current season?

|___|___|___|___| Tk.

14. If boats are self owned provide the following information?

Items	Boat # 1	Boat # 2	Boat # 3	Total
length (m)	|__|__|	|__|__|	|__|__|	|__|__|
width (m)	|__|	|__|	|__|	|__|__|
Tonnage	|__|__|	|__|__|	|__|__|	|__|__|__|
New/old when purchased	|__|	|__|	|__|	
Purchase price (Thousand Tk.)	|_|_|_|	|_|_|_|	|_|_|_|	|_|_|_|
Years in possession	|__|__|	|__|__|	|__|__|	|__|__|
Expected life	|__|__|	|__|__|	|__|__|	|__|__|
Current age	|__|__|	|__|__|	|__|__|	|__|__|
Current cost of a new boat (thousand Tk.)	|_|_|_|	|_|_|_|	|_|_|_|	|_|_|_|
Present Value (thousand Tk.)	|_|_|_|	|_|_|_|	|_|_|_|	|_|_|_|

15. Repair and maintenance cost per season (Tk.)

a. repainting |__|__|__|__|
b. hull repair |__|__|__|__|
c. repair/maintenance of sails |__|__|__|__|
d. maintenance of deck facilities |__|__|__|__|
e. other minor repairs |__|__|__|__|

16. What type of gear do you use in the current season?

|__|

Code 1 = gill net
2 = seine net
3 = drift net
4 = cast net
5 = drift net
6 = clap net
7 = hooks and line
8 = others

17. If you are using nets give the following information:

No. of sections |__|__|

Length of each section (m) |__|__|

Depth (m) |__|__|

Mesh size |__|__|

Purchase price (Tk.) |__|__|__|__|__|

No. of years in use |__|__|

Expected life |__|__|

Current value (Tk.) |__|__|__|__|__|

Cost of a new net (Tk.) |__|__|__|__|__|

18. Seasonal repair and maintenance cost of net (Tk.)

a. maintenance cost |__|__|__|__|__|
b. repair cost |__|__|__|__|__|
c. replacement cost |__|__|__|__|__|

19. Purchase of non-durable items in each season (Tk.)

a. kerosene lamp |__|__|__|
b. flashlight |__|__|__|
c. utensils |__|__|__|
d. others |__|__|__|

20. Weekly expenses on board (Tk.)
    a. minor repair of boat
    b. minor repair of sails
    c. repair of deck facilities
    d. repair of gear
    e. kerosene cost
    f. battery cost
    g. Others (specify)

21. Seasonal toll for fishing permit (Tk.)

22. Number of crew on-board in the current season

23. Daily expenses for food per crew on-board (Tk.)

24. Sharing system of net fishing income (%)

    a. ordinary crew
    b. head fisherman
    c. owner fisherman
    d. boat
    e. gear

Appendix C
List of Important Fish and Prawns Harvested from the Riverine Fisheries of Bangladesh*

Common Name	Family	Species	English Name	Habitat
Air	Bagridae	*Mystus aor*		F
		Mystus seenghali		F
Angrot	Cyprinidae	*Labeo angra*		F
Arwari	Bagridae	*Mystus menoda*		F
Baacha	Schilbeidae	*Eutropiicthys vacha*		F
Bagh aor	Bagridae	*Bagarius bagarius*		F
Bailla	Gobiidae	*Awaous grammepomus*	Scribbled goby	M
		Awaous stamineus		M
Baim	Mastacembelidae	*Mastacembelus armatus*	Spiny eel	F, B
Baitka	Cyprinidae	*Labeo pangusia*		F
Banspata	Cyprinidae	*Danio devario*		F
	Mugilidae	*Liza cascasia*	Yellow-tail mullet	M, B
		Liza oligolepis	Large-scaled mullet	M, B
		Liza tade	Green-back mullet	M, B
	Schilbeidae	*Ailia coila*		F
		Ailiichthya punctata		F
	Amblycipitidae	*Amblyceps mangois*	Torrent catfish	F
Bata	Cyprinidae	*Cirrhinus reba*	Reba	F
		Labeo bata	Bata	F
Batashi	Schilbeidae	*Pseudeutropius atherinoides*		F
Bele	Gobiidae	*Glossogobius giuris*	Bar-eyed goby	M, F
Bhadi punti	Cyprinidae	*Puntius stigma*		F
Bhangan	Cyprinidae	*Labeo boga*		F
Bheda	Nandidae	*Nandus nandus*		F
Bhetki	Centropomidae	*Lates calcarifer*	Barramundi (or Giant seaperch)	F
Bhol	Cyprinidae	*Barilius bola*		F
Bishtara	Scatophagidae	*Scatophagus argus*	Spotted scad	M often B
Boal	Siluridae	*Wallago attu*	Freshwater shark	F
Bojori tengra	Bagridae	*Mystus tengara*		F
Borguni	Theraponidae	*Therapon jarbua*	Crescent perch	M often B, F
Borong	Clupeidae	*Nematalosa nasus*	Long-ray bony bream	M
Chacunda	Clupeidae	*Anodontostoma chacunda*	Short-nose gizzard shad	M
Chalapunti	Cyprinidae	*Puntius chola*	Green barb	F
Chanda	Centropomidae	*Chanda nama*	Perchlet	F
Chandan ilish	Clupeidae	*Tenualosa toli*	Toli shad	M, F
Chapila	Clupeidae	*Gudusia chapra*		M
		Gonialosa manminna	Ganges gizzard shad	M
		Ilisha motius		M
Chatta chingree	Palaemonidae	*Macrobrachium malcolmsonii*	Monsoon river prawn	F, B
Chebli	Cyprinidae	*Danio aequipinnatus*	Giant danio	F
Checa	Chacidae	*Chaca chaca*	Squarehead catfis	F
Chela	Cyprinidae	*Oxygaster bacaila*		F
Chenua	Bagridae	*Sisor rhabdophorus*		F
Chep chela	Cyprinidae	*Chela atpar*		F
		Chela laubuca	Winged rasbora	F
Chingree icha	Atyidae	*Caridina gracilirostris*	Needlenose caridina	F, B
		Caridina propinqua	Bengal caridina	F, B
	Palaemonidae	*Leandrites celebensis*		F, B
		Leptocarpus fluminicola	Ganges delta prawn	F, B
		Leptocarpus potamiscus	Bombay prawn	M, B
		Macrobrachium biramanicum	Birma river prawn	F, B
		Macrobrachium dayanum	Kaira river prawn	F
		Macrobrachium idae	Orana river prawn	F, B
		Macrobrachium kempi		F, B
		Macrobrachium lamarrei	Kuncho river prawn	F, B

continued

Appendix C (continued)

Common Name	Family	Species	English Name	Habitat
		Macrobrachium lanchesteri	Riceland prawn	F, B
		Macrobrachium mirabile	Shortleg river prawn	F, B
		Macrobrachium palaemonoides		F, B
		Macrobrachium rude	Hairy river prawn	F, B
		Macrobrachium superbum		F, B
		Palaemon styliferus	Roshna prawn	M, B often F
		Palaemon modestus	Siberian prawn	F
		Palaemon karnafulianenis		F, B
		Palaemon serrifer spp.		F, B
		Palaemon semmelinkii spp.		F, B
		Palaemon olichodactylus	Goda river prawn	F
		Palaemon tenuipes	Spider prawn	M, B
Chiring	Gobiidae	*Apocryptes bato*		F
		Pseudapocryptes bato		F
Chital	Notopteridae	*Notopterus chitala*		F
		Notopterus notopterus		F
Choukka	Clupeidae	*Pellona ditchela*	Toothed shad	M
Chuna	Anabantidae	*Colisa chuna*		F
Chunobele	Gobiidae	*Gobiopterus chuno*		F
		Periophthalmodon schlosseri	Pug-headed mud skipper	F, B
		Periophthalmus barbarus		B
Chunobele	Taenioididae	*Taenioides cirratus*		M, B
Churi	Trichiuridae	*Trichiurus haumela*	Largehead hairtail	M
		Eupleurogrammus muticus	Smallhead hairtail	M
		Lepturacanthus savala	Savalai hairtail	M
Dahuk	Gobiidae	*Boleophthalmus boddarti*	Goggle-eyed goby	F
		Scartelaos viridis	Bearded goby	F
Darkina	Cyprinidae	*Esomus danricus*		F
		Rasbora daniconius	Common rasbora	F
		Rasbora rasbora		F
Datina	Sparidae	*Acanthopagrus datnia*	Japanese silver bream	M
Dhal magur	Bagridae	*Glyptothorax botius*		F
		Glyptothorax telchitta		F
Dimua chingree	Palaemonidae	*Macrobrachium villosimanus*	Dimua river prawn	F
Dolichewa	Gobiidae	*Parapocryptes batoides*		F
Elang	Cyprinidae	*Rasbora elanga*		F
Gachua	Channidae	*Channa gachua*		F
Gang magur	Plotosidae	*Plotosus canius*	Striped catfish eel	M
Gang tengra	Bagariidae	*Gagata gagata*		F
		Gagata viridescens		F
		Gagata youssoufi		F
		Gagata nangra		F
Ghaura	Schilbeidae	*Clupisoma garua*		F
Ghonia	Cyprinidae	*Labeo gonius*		F
Ghor poa	Cyprinidae	*Garra annandalei*		F
		Garra gotyla		F
Ghora mach	Cyprinidae	*Labeo dyocheilus*		F
Ghorachela	Cyprinidae	*Oxygaster gora*		F
Gilipunti	Cyprinidae	*Puntius gelius*		F
Golda chingree	Palaemonidae	*Macrobrachium rosenbergii*	Giant river prawn	F , B sometimes M
Golsha	Bagridae	*Mystus bleekeri*		F
Golsha tengra	Bagridae	*Mystus cavasius*		F
Goti poa	Sciaenidae	*Otolithes maculatus*	Spotted croaker	M
Goti poa	Toxotidae	*Toxotes chatareus*	Spotted archerfish	F, B
Gozar	Channidae	*Channa marulius*		F
Guji	Bagridae	*Mystus aor*		F
Gura tengra	Bagridae	*Leiocassis rama*		F
Hail chanda	Stromateidae	*Parastromaeus niger*	Brown pomfret	M
Ilish	Clupeidae	*Hilsa ilisha*	Hilsa shad	M

continued

Appendix C (continued)

Common Name	Family	Species	English Name	Habitat
Jarki	Gerreidae	*Gerres setifer*	Black-tipped silver biddy	B
Jarua	Cyprinidae	*Changunius chagunio*		F
Jaya		*Aspidoparia jaya*		F
Joya	Cyprinidae	*Barilius bendelisis* var *chedra*		F
Joyakhoksa	Cyprinidae	*Barilius bendelisis* var *cosca*		F
Kajuli	Schilbeidae	*Ailia coila*		F
		Ailiichthya punctata		F
Kala bata	Cyprinidae	*Crossochilus latius*		F
Kala datina	Sciaenidae	*Johnius diacanthus*	Two-spined croaker	M
Kalibaush	Cyprinidae	*Labeo calbasu*	Orange-fin labeo	F
Kanchanpunti	Cyprinidae	*Puntius conchonius*		F
Kanchki	Clupeidae	*Corica soborna*	Ganges river sprat	M, B
Kani pabda	Siluridae	*Ompok bimaculatus*	Butter catfish	F
Kani tengra	Bagridae	*Glyptothorax cavia*		F
		Laguvia ribeiroi		F
		Laguvia shawi		F
		Pseudecheneis sulcatus		F
Katla	Cyprinidae	*Catla catla*	Catla	F
Kete	Cyprinidae	*Osteochilus* spp.		F
		Rohtee cotio		F
Khaksa	Cyprinidae	*Barilius barna*		F
		Barilius shacra		F
		Barilius vagra		F
Kholisha	Anabantidae	*Colisa fasciata*		F
Khorsula	Mugilidae	*Rhinomugil corsula*	Mullet	M
Koi	Anabantidae	*Anabas testudineus*	Climbing perch	F
		Macropodus cupanus	Palmyra-fibre fish	F
Koitor	Sciaenidae	*Johnius coitor*	Ganges croaker	M
Koli	Eleotridae	*Eleotris fusca*	Brown gudgeon	F, B
Kuli	Eleotridae	*Butis butis*	Flat-headed gudgeon	B
		Eleotris lutea		F, B
Kursha	Cyprinidae	*Labeo dero*		F
Kuta kanti	Bagariidae	*Conta conta*		F
		Erethistes pussilus		F
		Hara hara		F
		Hara jerdoni		F
Lakhua	Polynemidae	*Polynemus indicus*	Indian threadfin	M
Lalkhoilsa	Anabantidae	*Colisa lalia*		F
Magur	Clariidae	*Clarias batrachus*	Walking catfish	F
Mahashol	Cyprinidae	*Tor putitora*		F
		Tor tor	Mahsier	F
Meni	Nandidae	*Nandus nandus*		F
Mola	Cyprinidae	*Amblypharyngodon microlepis*		F
		Amblypharyngodon mola		F
Molapunti	Cyprinidae	*Puntius ambassis*		F
Morar	Cyprinidae	*Aspidoparia morar*		F
Mrigal	Cyprinidae	*Cirrhinus mrigala*	Mrigal	F
Muribacha	Schilbeidae	*Clupisoma garua*		F
Nandil	Cyprinidae	*Labeo nandina*		F
Neptani	Anabantidae	*Ctenops nobilis*		F
Nipati	Cyprinidae	*Danio dangila*		F
Nuna baila	Gobiidae	*Acentrogobius caninus*	Dog-toothed goby	M, B
		Acentrogobius cyanomos		M, B
		Acentrogobius puntang	Silver-spotted goby	M, B
		Acentrogobius viridipunctatus	Green-spotted goby	M, B
		Brachygobius nunus		M, F
		Oxyurichthys microlepis	Small-scaled goby	M
		Pogonogobius planifrons		M, F
		Stigmatogobius oligactis		M, F
		Stigmatogobius sadanundio		F, B

Appendix C (continued)

Common Name	Family	Species	English Name	Habitat
Nuna tengra	Bagridae	*Mystus gulio*	Long-whiskers catfish	F
Pabda	Siluridae	*Ompok pabda*		F
Pangas	Pangasiidae	*Pangasius pangasius*		F
Pankal baim	Mastacembelidae	*Mastacembelus pancala*	Spiny eel	F
Parshe bata	Mugilidae	*Liza parsia*	Gold-spot mullet	M
Pathar chata	Cyprinidae	*Barilius tileo*		F
Pholi	Notopteridae	*Notopterus notopterus*		F
Pholichanda	Stromateidae	*Pampus argentus*	Silver pomfret	M
Phoolchela	Cyprinidae	*Oxygaster phulo*		F
Phopa chanda	Centropomidae	*Chanda beculis*		F
Phutanipunti	Cyprinidae	*Puntius phutunio*	Cuming's two-banded barb	F
Poa	Sciaenidae	*Pama pama*	Long-finned croaker	B
Punti	Cyprinidae	*Puntius puntio*		F
		Puntius titus		F
Raja chewa	Taenioididae	*Odontamblyopus rubicundus*		M, B
		Taenioides buchanani		M, B
Ranga chanda	Centropomidae	*Chanda ranga*		F
Rayeg	Cyprinidae	*Cirrhinus reba*		F
Rita	Bagridae	*Rita rita*		F
Rui	Cyprinidae	*Labeo rohita*	Rohu	F
Rupchanda	Stromateidae	*Pampus chinensis*	Chinese pomfret	M
Shada chewa	Taenioididae	*Trypauchen vagina*	Burrowing goby	M
Shilong	Schilbeidae	*Silonia silondia*		F
Shing	Heteropneustidae	*Heteropneustes fossilis*	Stinging catfish	F, B
Shol	Channidae	*Channa striatus*		M
Shorpunti	Cyprinidae	*Puntius sarana*		F
Sinia	Bagridae	*Gagata cenia*		F
Tailla	Polynemidae	*Eleutheronema tetradactylum*	Four-finger threadfin	M
Tak chanda	Gerreidae	*Gerres filamentosus*	Whipfin silver biddy	M
	Leiognathidae	*Leiognathus equulus*	Greater ponyfish	M
		Secutor insidiator	Slender-barred ponyfish	M
		Secutor ruconius	Deep-bodied ponyfish	M
Taki	Channidae	*Channa punctatus*		M
Tara baim	Mastacembelidae	*Macrognathus aculeatus*	Lesser spiny eel	M
Tengra	Bagridae	*Batasio tengana*		F
		Mystus vittatus	Striped dwarf catfish	F
Tiashol	Channidae	*Channa barca*		F
Titpunti	Cyprinidae	*Puntius ticto*	Fire-fin barb	F
Topshi	Polynemidae	*Polynemus sexfilis*	Golden sixthread tesselfish	M
		Polynemus paradiseus	Paradise threadfish	M

*Adapted by V. Sambilay, Jr. (ICLARM) and the author with corrections and addition of English common names and of habitat definition (M = marine, B = brackish and F = freshwater) from: Rahman, A.K. 1974. A checklist of the freshwater bony fishes of Bangladesh. Fisheries Research Station Bull. 1, Chandpur, Bangladesh and Kibria, G. and K.M. Ahmad. 1983. Prawn fisheries in Bangladesh. National Symposium on Agricultural Research, Bangladesh Agricultural Council, Bangladesh.

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