Chapter 7

Conclusion

7.1 The absence of optimum decision-making process in natural resource management is a major concern of government, policy makers, non-government agencies of conservationists of nature, managers and economists. The reason behind this great concern is due to the fact that extravagant exploitation of natural resources may prove to be disastrous both for economy and ecology. Bangladesh is not only an underdeveloped country of small in geographical size but also with less natural resources and population burden. Efficiency in management of natural resources imply that the appropriate application of managerial techniques which are dealt with in the subject called''Operations Research' (OR) is an imperative. In this respect, Bangladesh, like any other under-developed country, has become a technological and psychological laggard leading to wasteful utilization of resources. With a view to long-run sustainability, the study of current practices of resource management is needed to find out the problems and scope of improving managerial efficiency in each and every sector of natural resource. It has already been proved by many recent studies that through improved managerial efficiency by applying OR-techniques, the social benefit can be enhanced in short-run and can be optimized for conservation and sustainability in the long-run. The present thesis is a humble attempt to study the existing management practices in commercially exploited marine shrimp fishery of Bangladesh with a view to identifying the scope and problems of applicability of such OR-techniques. The marine fish being a biological species having regeneration capacity involves population dynamics. This dynamics is complex as uncertainties are present in unpredictive character of ecological and economic factors. This thesis, therefore, humbly attempts to provide a suitable dynamic model which could offer a feedback rule for optimal management of this renewable resource.

Chapter 2 provides a brief description of fishery resources in Bangladesh. However, as our objective is to study optimal utilization of marine shrimp, a separate section deals exclusively with different aspects of marine shrimp.' This section contains topological description of harvesting zone, details of trawlers along with the discussion on biological description of shrimp family. The information and data provided in this chapter reveal that Bangladesh is not very rich in natural resources of non-renewable nature but has a great potential in utilizing renewable resources fruitfully and effectively. Movement of number of trawlers over time shows that the industry suffered from a crowding problem a few years after initiation of commercial harvesting of shrimp and possibly reached an open-access equilibrium point. The regulation thereafter has brought back the industry to an economically viable equilibrium point at present.

Formulation of dynamic optimization model of any marine resource requires time series data of effort and harvest level along with a set of bioeconomic parameters, namely, carrying capacity <K), intrinsic growth rate (r), catchability co-efficient (q), parameters of demand and cost function. But the top of the requirement is time series data of estimated biomass stock (x). While the first two time series data are available, the occasional survey estimates of biomass stock are available instead of time series. In chapter 3, we have attempted to estimate said bioeconomic parameters. On the basis of trawlers' specification

and marine characteristics, the estimation of biomass stock of marine shrimp in the exclusive harvesting zone of Bangladesh in Bay of Bengal for the period 1981-82 to 1997-98 has also been made by applying Pauiy's method. On the basis of the annual biomass stock, the expected level of harvest has been predicted for the given actual effort level. The analysis of the result shows that the calculated level of harvest differs insignificantly from the actual level of harvest and thus confirms the validity of the biomass estimation. The result also shows that the estimated biomass stocks predominantly lie within the lower and upper limit given by one of the surveys made by Penn.

In chapter 4, we have formulated a non-linear dynamic model of Bangladesh trawl shrimp fishery for optimal control with discrete-time. The model is such that it maximizes present value of net benefit subject to harvest and growth constraints. The solution of the model provides optimal (steady state) level of biomass stock, harvest level, effort level and shadow price. The comparative study of actual and optimal harvest, stock and effort given by approach paths for non-linear exponential demand condition reveal that marine fishery is not managed and utilized optimally at present in Bangladesh for both under static, and dynamic situations. The country thus bears loss due to non-optimal allocation of marine shrimp resource. The chapter provides annual loss in each year and approximate cumulative loss of the whole period. Both type of losses are appeared to be substantial in amount..However, the analysis shows that the steady state may be attained by the system very quickly. It seems that marine shrimp fishing of Bangladesh would probably take less time and cost to recover if corrective measures are taken. Both the actual level of harvest and biomass stock being much less than the optimal value, the study also indicates that the danger of gradual depletion of the resource leading to extinction cannot be ruled out.

A study on application of non-linear dynamic optimization (continuous-time) has been taken up in chapter-5 for optimal control of the resource and in order to have an optimal feedback rule for management of Bangladesh trawl shrimp fishery. A non-linear dynamic optimization model has been formulated, which integrates the discounted net revenue with infinite time horizon. Stock is assumed to be converging to steady state biomass level as time tends to infinity. The functional is optimized subject to the constraints of harvest, growth and time derivative of biomass. The current value Hamiltonian is obtained and the solution of the optimal control problem provides a highly non-linear ordinary differential equation, which is then solved by applying Sandal and Steinshamn procedure with zero and non-zero discounting factor. Algorithms for both zero and non-zero discount rate have been provided in this chapter. The study gives optimal values of harvest, biomass stock, effort level and shadow price. It is observed that the difference between the optimality under continuous and discontinuous time is insignificant. The study gives the optimal control path which enables to provide minimum viable level of the resource. Analysis of the result shows that the optimal control path does not vary significantly with the social discount rate and thereby substantiates the theoretical findings of Farzin (1984), Hannesson (1983/1987) and Sandal and Steinshamn (1997). The calculated value of minimum viable level for non-linear demand situation appears to be consistent with the expected theoretical value. The value of minimum viable level seems to be a possible danger of extinction if the present practice of harvesting is continued though the estimated biomass level at present may not considered to be indicative of very close to our calculated minimum viable level. Like discontinuous case, the notional loss has been calculated for a particular year. The chapter provides the feedback rule which represents control variable as a function of state variable. A schema under the context of Bangladesh has been provided for implementing such rule.

In the next chapter of the thesis, the chaotic dynamics and catastrophic discontinuities of Bangladesh trawl shrimp fishery have been studied under consistent expectations equilibrium (CEE) paradigm, as we have found that the supply curve is backward bending with non-zero discount rate. As it is known that backward bending supply curve may cause multiple equilibria and the shifting of demand may result in sudden jump to a new equilibrium position, there exists a possibility of catastrophic discontinuities. Rational expectations hypothesis (REH) being found extremely stringent for the reason of underlying implicit requirement of perfectly complete information set, the consistent expectations equilibrium (CEE) is considered as more plausible through self-fulfilling mistake under adaptive learning process. The study shows that Bangladesh trawl shrimp fishery is deterministically chaotic and converges to the 'good' steady state CEE inspite of the fact that at non-zero discount rate demand curve exhibits tangent bifurcation. Simulation of the SAC learning dynamics under AR (1) belief process suggests that convergence to this 'good' equilibrium steady state is the outcome of the SAC learning process. The belief parameters are determined and shown. Simulated results show that all the parameters of the triple {p*,a*,p*) of CEE converge to a stable steady state and a 'good' CEE is deterministically possible subject to rational adaptive learning behaviour of economic agents involved in marine shrimp exploitation in Bangladesh.

7.2 Scope of Further Studies:

In Chapter-2, we discussed the present scenario of shrimp fishery in Bangladesh (section 2.2). Life cycle patterns of Penaeid Shrimp and practice of harvesting by different types of nets at various stages in Bangladesh are also discussed. We observed that a substantial portion of artisanal catch is at juvenile stage (Table-2.3). Moreover, the discussion shows that no records on how much shrimp is harvested at pre-juvenile stage are available. It, therefore, indicates that trawl shrimp fishery is affected by the artisanal fishery. The result could have been much more meaningful and significant had the artisanal fishery been incorporated in our study. Since, no systematic and official records or data on this aspect are available, an extensive survey is required for this purpose. Further studies in this direction could be undertaken.

Our attempt to estimate the actual demand function indicates that price is possibly exogenously determined. A study could be undertaken to study the non-linear dynamics of marine fishery considering price as an exogenously determined factor. A separate study could be undertaken to estimate the loss due to non-optimal harvesting of resources, as we have already mentioned in sections 4.3 and 5.5, incorporating adverse effects on ecology and environment.