Traditional Ecological Knowledge and its Importance for Conservation and Management of Freshwater Fish Habitats of Bangladesh

By

Abdullah-Al Mamun

A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
For the Degree of

Master of Natural Resource

Management

Natural Resources Institute
University of Manitoba
Winnipeg, Manitoba
January, 2007

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION

Traditional Ecological Knowledge and its Importance for Conservation and Management of Freshwater Fish Habitats of Bangladesh

BY

Abdullah-Al Mamun

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

Master of Natural Resources Management

ABSTRACT

This thesis focuses on the value and policy implications of traditional ecological knowledge of fishers for restoration and conservation of fish habitats in Bangladesh where ecosystems are highly altered. About one-third of Bangladesh consists of floodplains. Efforts to "control" floodwaters have resulted in the modification of this waterscape and the alteration of wetland habitats. However, the main source of protein in Bangladesh is floodplain fisheries, and fish are important for the livelihoods of millions. Hence, environmentally favorable practices have evolved among fishers, and many of these pertain to fish habitat management.

The study was undertaken with the purpose of identifying traditional fisheries knowledge relevant to restoring degraded floodplain fisheries, and carried out in *Chakuso* Lake (a beel system) in northcentral Bangladesh. The results indicate that there is a rich reservoir of traditional ecological knowledge held by fishers with respect to hydrology of floodplains and small lakes, habitat preferences of fish, role of aquatic vegetation as habitat components, and impacts of habitat disturbances due to human interventions in aquatic ecosystems.

Fishers' management practices and techniques include habitat management, as in the construction of fish sanctuaries; use of traditional *kata* (brush-pile) fishery systems that function as seasonal fish sanctuaries; maintenance of fish habitat connectivity; conservation of certain indigenous varieties of rice that seem to provide favorable fish habitat; use of traditional water treatment and fish disease control techniques; and the removal of old canals and water control structures that tend to fragment fish habitat and interfere with seasonal movements. As pragmatic solutions to habitat degradation problems, many of these locally-evolved practices and approaches are cost-effective, environmentally friendly and culturally acceptable. The research argues for a holistic approach to fish habitat management that ensures multi-level cooperation involving fishers and government managers, and builds on the knowledge and credibility of resource users.

ACKNOWLEDGEMENTS

I feel fortunate to get Professor Fikret Berkes, Canada Research Chair, not only as my advisor, but as a mentor and would like to express my gratitude for his encouragement and guidance throughout the study. Much of the analysis and theoretical development in this thesis would not have been possible without his patient review, comments and suggestions. His contributions to the thesis and to my comprehension of issues in the area of the traditional ecological knowledge of fisheries have been invaluable. With equal gratitude, I also would like to thank, the two members of my committee, Professor Emdad Haque, Director, Natural Resources Institute, University of Manitoba, Canada and Dr. Helen Fast, Freshwater Institute, Department of Fisheries and Ocean, Canada. Both provided me with their valuable time, support and insight during the course of this study. My sincere thanks go to the WorldFish Center, Bangladesh for helping with the research through a partnership arrangement with Natural Resources Institute. I also acknowledge the inputs and guidance from Dr. M. A. Rab, Project Scientist, and Community-Based Fisheries Management Project of Bangladesh during my field activities.

My special thanks are for the following individuals and institutions for financial support to carry out the research:

1. WorldFish Center, Bangladesh Office.
2. Canada Research Chair, Community-based Natural Resources Management.
3. SSHRC project on local knowledge of floodplains (Dr Emdad Haque, P.I.)

Many individuals have made this thesis possible. My special thanks to my friends Jackie Rittberg And Ron Jones, Natural Resources Institute, University of Manitoba, for their assistance in editing the manuscript. I extend my thanks to my colleagues at WorldFish Center, Bangladesh who gave their time to discuss various issues related to fish habitat restoration and conservation, and to Mahbubul Alam, Associate Professor, Independent University of Bangladesh, who helped me in the analytical stage of the research.

Finally, to my wife Lita, daughter Jaisee and son Nafis, for their patience and encouragement throughout the duration of my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of frequently used acronyms and local names

Ayre	Medium-sized cat fish
Baim	Freshwater eel
Beel	Natural depression found mostly in floodplains
Ber jal	Seine net targeted small to medium-sized fish
Boal	Freshwater catfish weighing about 30+ kgs.
Bonna/ baan	Flood
Boro	Type of dry season rice farming
BMC	Beel Management Committee
Chanda	Small glass perch
Chela	Small minnow
Current Jal	Gill net
CNRS	Center for Natural Resources Management
Darkina	Small minnow
DOF	Department of Fisheries
Doab	River scour
Ghola pani	Murky water
Gharani	A local NGO working in the study area
Gozar	The largest member of channid fish found in Bangladesh
Gutum	Loach
Gura icha	small shrimps
Haor	Large natural depression found in northeastern Bangladesh
Hilsa	River shad
Jele	Traditional Community fisher
Khal	Natural canal
Koi	Local perch fish
Kata	Brush park (brush pile) used as both sanctuary and fish aggregating device
Kua	Submerged ponds/ditches. A version of kata
Kala pani	Clear water
Magur	A sillurid cat fish
MACH	Management of Aquatic Resources through Community Husbandry
Meni/Bheda	A local perch
Mola/dhela	Medium-sized minnow
Nola	Juvenile of various carp
Pona	Juvenile from all fish groups
Puti	Small to medium-sized minnow
Rakhkhushe maach	carnivorous fish
Rita	Medium-sized catfish
Rui, catla, and mrigal	Local major carps
Shing	A local sillurid fish
Taki/raga	Channid fish
Tengra	Small cat fish.
Ujan	Upstream area of rivers
Bhati	Downstream area of rivers
WFC	WorldFish Center

CHAPTER 1: INTRODUCTION

1. Context

The inland capture fisheries of Bangladesh are complex ecologically and socially. Multi-species and multi-gear fisheries are spread through a range of water body types interlinked into a wider floodplain system (Thompson 1997). Inland waterbodies of Bangladesh are comprised of small and large rivers, seasonal floodplains, perennial saucer-shaped natural depressions (called *beel*) oxbow-lakes (called *haor*), and canals. The inland fisheries are multi-species and may involve as many as 261 species (Mamun 2005; Rahman 1989). Many waterbodies used as fisheries resources are seasonal in nature (for example, floodplain beels) and are important components of diverse ecosystems. In addition, there are waterbodies with perennial nature (for example, rivers and deep beels). These waterbodies exhibit both spatial and temporal variations in their size, shape, and depth. These variations influence fish biology and life history of natural fish by providing habitats for over-wintering (for example deeper rivers), feeding and nursery grounds (for example flooded lands and shallow beels). These variations are also responsible for maintaining the fish stocks and movement patterns in between habitats. As a result, maintaining the habitat dynamics is very important, and is a challenging task for management of inland fisheries.

The Department of Fisheries (DoF) of the Government of Bangladesh has overall management responsibility for open water fisheries. The DoF has been enforcing the Protection and Conservation of Fish Act, 1950 as a part of their major fisheries management related activities. The Act mainly focuses on the management of important local major carps (*rui, catla, and mrigal*) and *hilsha* (river shad) fisheries and several other fish of commercial importance. The management of those species includes the prohibition of juvenile catch; maintaining closed seasons during spawning times (May-August). It also restricts the use of certain gears and traps (for example: small mesh seine net locally called *ber jal*) that are considered destructive to fisheries. Unfortunately, in the management policy there has been no management status for many other local indigenous species found in inland water with respect to conservation and there is no clear indication for habitat conservation (Thompson et al. 2000). These local species, however, contribute a great majority of the catch. It is, thus, evident that the Act of 1950 and its subsequent version Protection and Conservation of Fish

(Amendment) Act 1995 (Bangladesh Gazette 1995), hardly fulfill the present day needs to fisheries management. In addition, these Acts do not include a component that properly deals with other causes of fish decline such as impacts from water control structures (e.g. flood control and irrigation schemes) and habitat destruction by roads, and natural siltation, along with overfishing, have been commonly cited as causes of the deterioration of the country's fisheries resources (Ali and Thompson 2006; Hughes et al. 1994; Ali 1997).

In addition to the Fish Act 1950 and its amended version called "Protection and Conservation of Fish (Amendment) Act, 1995", there are various national plans and policies related to fish conservation and management. For example, Bangladesh National Fifth Five Year Plan (1996-2000). It emphasized on the improve environmental conditions with respect to biological and institutional management mechanisms for judicious use on fisheries resources (Parvin and Islam 2002). Similarly, the National Fish Policy of 1998 emphasized on the maintenance of ecological balance, and conservation of biodiversity. The policy outlines that:

....To conserve fish habitats from damage, appropriate care should be taken during the implementation of all developmental activities such as flood control, irrigation and drainage (FCD/1) projects, agriculture, industries, road and urban development projects (Section 6.1). It is further stated that breeding grounds of fish and freshwater giant prawn will be conserved (Section 6.5).

Several other policies are also available that laid out various provisions for fisheries management in parallel with national fisheries policies and acts. The National Environmental Policy of 1992 was formulated to achieve the objectives of environmental improvement and focused on ensuring appropriate environment for the conservation and development of fisheries and preventing the activities which diminish wetlands/natural habitats of fish. It encourages and called for rehabilitative measures in areas damaged due to water resources development and flood control. Similarly, several provisions have been made in the National Water Policy 1997 which reads as follows:

(i) Fisheries will receive due emphasis in water resources Planning when the anticipated social impact is high; and

(ii) Attempt will be made to keep the impact on natural aquatic environment to a minimum.

It is evident that the government of Bangladesh has already made substantial efforts to develop necessary acts, plans and polices relevant to management of fisheries. However, these acts and other regulatory measures have not effectively improved fisheries management because of lack of follow up and implementation. Thus these management tools have not prevented the degradation of fisheries (Kabir and Khan 2004; Farook 1999). As a result, open water fisheries of Bangladesh have been declining, especially during the last two decades. There are no reliable statistics on open water fish catch. Various records (Ahmed et al. 2003; Thompson et al. 2003), anecdotal information and my observations indicate a production decline of some 60-70% since the 1970s. The decline in open water catch has been a serious issue for Bangladesh as millions of rural households depend on fishing to maintain their livelihood incomes, and because fish is a major protein source in Bangladesh (Thompson et al. 2003).

However, the government is addressing the issue in a number of ways, such as: (i) moving towards biological management from revenue-oriented management; (ii) involving resource users in capture fisheries management to maintain natural productivity; and (iii) starting programs such rehabilitating of degraded habitats (FAO 1999).

For effective fisheries management and habitat conservation, a clear understanding of the biophysical features of the fisheries regarding habitat dynamics and fish stocks, movement patterns, seasonality, and habitat selection of fish is important (Johannes et al. 2000). Carryout new studies in the respects to generate information that support management is somewhat impossible for a developing country like Bangladesh. The knowledge held by local fishers who traditionally engage in fishing for commercial, livelihoods and subsistence purposes can be viewed as a useful tool for managers trying to manage fisheries in a sustainable way. Therefore, an integration of fishers' traditional ecological knowledge with conventional management systems may help ecological restoration. The incorporation of fishers' ecological knowledge into conventional management systems has the potential to help fisheries researchers and managers to understand the ecology and fisheries resources and can help build credibility with local communities. Building credibility could help in creating shared vision in fisheries management. Studies with respect to traditional ecological knowledge of fisheries in Bangladesh are scant. However, few studies emphasized on the richness of fisher ecological knowledge in Bangladesh and highlighted the importance of incorporation of fisher knowledge into mainstream management and argued that it may play an important role in restoring degraded floodplain fisheries of Bangladesh (Thomson et al. 2003; Sillitoe 2000).

In the recent time, various studies are done with respect to the use of traditional knowledge in natural resources management and considered use of such knowledge as vital for sustainability of natural resources. These studies emphasized that fisheries management without in-depth understanding of the socio-ecological dimensions may fail and can result in conflict between stakeholders and lead to uncertainty in management. As a result, expected outputs from management efforts may not be achieved (Berkes 2004; Kapoor 2001; Pandey 2003; Agarwal 1995) It is argued that traditional ecological knowledge can help decrease uncertainty in fisheries science, and this knowledge can help in gaining a better understanding of functional systems (Freeman 1992). However, exploring the realm of indigenous knowledge in relation to fisheries science has historically been ignored due to quantitatively based decision-making frameworks employed by the fisheries managers (Gallagher 2002). Complementing scientific information with traditional knowledge is becoming more prevalent with the acceptance of alternative (i.e. non-scientific/postpositivistic) forms of "knowing" (Berkes 1999; Johnson 1992; Wolfe et al. 1992).

Concerned are raised with respect to the integration of traditional ecological knowledge into conventional management systems. It is argued by Nadasdy (1999) that interaction between traditional knowledge and science has been fraught with appropriation of knowledge and compartmentalization, distillation and misinterpretation of information from a scientific perspective. Inevitably such interactions occur due to the interpretation of one form of knowledge through the epistemology of another. Working together, and learning from one another to promote a collective knowledge base for a better understanding of ecosystems and cultures, should be the primary idea behind applying traditional ecological knowledge into scientific research and management (Gallagher 2002). Integrating indigenous knowledge into scientific research can permit scholarly exchange and growth, and empower a community (Colorado 1988). The word "integration" needs to reflect a blending of research efforts and not the domination or extension of ideological control by one another (*Ibid*).

Fishing takes place according to habitat features, seasonality, movement, patterns, size and abundance of fish and fisheries engaged themselves with fisheries activities more times than the fisheries managers and scientists do. Given the long term as well as historical livelihood relevance of fishers with water body dynamics and fishing, it is natural that fishers possess a vast knowledge with regard to stocks and habitats (Neis et al 1996). It is widely believed that modern fisheries knowledge is inadequate for solving present complex fisheries problems. Understanding fisheries resource dynamics with respect to biophysical characters and identifying management problems with the help of the traditional fisher knowledge might help sustainable management. Fishers' knowledge also can help qualitative and quantitative characterization of the fisheries. Incorporating local fisheries knowledge into conventional management with respect to ecology and biology may ensure a thorough approach to management. It will benefit both the communities and managers dealing with issues of habitat conservation and restoration.

Keeping the above management perspectives in the forefront, anticipatory research was done to assess the contribution of both sources of knowledge-western and indigenous-with regard to conservation of the fish habitats of floodplain fisheries in Bangladesh. The purpose of the thesis was not to prove the validity of one source of knowledge over the other. Rather, it admits that both sources of knowledge are valid in their own right and are complementary to each other.

1.2 Problem Statement

Due to human interactions and natural causes, the vast inland fisheries of Bangladesh have been declining rapidly and management measures are considered inadequate in resisting the decline of fish resources in inland waters. Like many parts of Bangladesh, community fishers, subsistence fishers, fish traders, landowners, local community- and political leaders and fisheries managers in north-central Bangladesh all are concerned about the sustainability of fisheries under current fisheries management approaches. It is believed that the responsible agencies (Directorate of Fisheries and Water Development Board of Bangladesh) have very little access to the management information needed for the management. The fishers of deltaic Bangladesh are likely to be a repository of the traditional ecological knowledge helpful for fisheries management. This knowledge can help to restore degraded floodplain fisheries. Though fishers' traditional knowledge and public participation are considered vital tools for managing natural resources, their use in management processes are not evident. As in other parts of the world, traditional ecological knowledge of fisheries is not optimally used in Bangladesh. It is widely believed that there has not been enough progress in the management and conservation of open water fish in Bangladesh. As a result, declining trends in production, along with extirpation (local extinction) of many species of fish, has been continuing. The identification of the real problems, proper planning in addressing them and the realistic implementation of development projects to achieve management goals of inland fisheries remain inadequate. In this context, examining and using the ecological knowledge of local fishers may serve as an important source of information for a better understanding of fish habitats and help in the designing of conservation/rehabilitation strategies. Combining traditional ecological knowledge with contemporary fisher knowledge, related to fish conservation, may provide a strong basis for long-term management of fisheries.

1.3 The goal and objectives of the study

It is expected that the results of this study may help better management of fisheries and benefit the community by ensuring long-term sustainability of the inland openwater fisheries. The goal of this study is to identify and document the present status of traditional ecological knowledge and practices regarding fish habitats and conservation measures, and to help formulate strategies and guidelines for sustainable management of inland fisheries in Bangladesh. Within the purview of the above, the main objectives of the study were:

1. To identify any local and traditional fisher knowledge relevant to restoring degraded floodplain fish habitats.
2. To identify the role of fishers' knowledge in development and management that targets to restore degraded floodplain fisheries.
3. To investigate policy implications of fishers' knowledge in conservation and management of fish habitats.

Given the three objectives, the kind of fisher knowledge that is important for this thesis is mainly about (i) fish species, their behavior, migrations, reproduction and productivity, and (ii) fish habitat, their identification, role of different kinds of habitats for different fish species, role of plants and habitat degradation. Except for section 5.2.3, the thesis does not go to any extent into the area of values, ethics and beliefs that are also part of traditional ecological knowledge.

1.4 Methods

WorldFish Center Bangladesh was the lead research support organization. They provided office facilities during the study. WorldFish Center also supported field level investigation by advising *Gharani* (a local NGO) who has been working in the study area. Before starting the field work, six possible working areas of WorldFish Center Bangladesh were primarily selected. Site selection was followed by a ranking analysis using a matrix table that was developed during the proposal submission related to the research. Several attributes were considered in selecting sites (Table 1).

Out of six sites, the *rajdhola beel* site was considered most suitable. But in the final selection, a new site called "*chakuso*", having features similar to *rajdhola beel,* was found as a good replacement. Some sites were not considered for reasons such as lack of transportation facilities and absence of various attributes.

Table 1. Matrix for rationale of choice of study site

CBFM sites	Suitable for TEK Research	Local level Governance	Familiarization with the project	Problem solving	Interesting "story" for study	Transportation	Rank (according to how many +)
Asura beel	+	+	++	+	++	+	8
Rajdhola beel	+	++	++	++	++	++	11
Dhumnodi beel	+	++	++	++	++	+	10
Shakla beel	+	+	+	+++	++	+	9
Guakhola-Hatiara clusters	++	++	++	++	++	+	11
Hamil beel	+	++	++	–	+	++	8

(Note: + + =favourable, + =possible, – = not possible)

Accomplishment of the thesis was done by consulting available archival records on fish habitat management programs and supplemented by field data that I gathered at the time of my field investigation from July to November 2005. The entire study was divided into three phases (Table 2).

In the first phase, I reviewed archival records available in government libraries and some other development organizations that work in open water fisheries management. These included the Department of Fisheries (DoF), WorldFish Center Bangladesh, IUCN (International Union for Conservation of Nature and Natural Resources), Bangladesh, CNRS (Center for Natural Resources Studies) and Department of Zoology, Dhaka University. The number of documents related to habitat management was found to be scant. However, the study of the available records provided the information about the current development on the management of fisheries in open water.

The second phase of the study included finalizing the site selection and discussion of research ideas/methodologies with NGOs, local community and district level DoF officials. Field work was initiated by disseminating research ideas to local government officials, and NGO and local fishers/stakeholders. At this point, specific PRA (Participatory Rural Appraisal) tools (Chambers 1994) included semi-structured interviews, key informants/focus groups, resource mapping, and seasonal calendars were applied. I conducted two separate meetings at community level related to focus group discussion and a resource mapping exercise. In addition, I participated in several community meetings related to management and planning of the water body. This participation provided me with the opportunity to be familiar with the community people as well as discussing my research issues and management problems with a larger audience to facilitate me in achieving in-depth information for the study area. Included in the discussion were habitat features, processes of degradation, hydrology, land-use patterns, resource changes and management conflicts and issues. A total of four (north, south, east and west) transects were done. In each transect, a community member was involved in helping me to direct the work and identify different land use patterns along the transect. They also helped me to investigate each specific area under particular use. Transect walks provided a detailed information of the land use pattern in the study area and the impacts of land use to the fish habitats.

Table 2. Timeline of the field study accomplishment

Activities	Date
Phase 1. Reviving reports/literature related to environmental issues and habitat management	July 2005
Phase 2. a) Finalize site selection b) Orientation: Introductory meetings with DoF officials, NGOs and stakeholders/fishers c)Main fieldwork: i) Transect walks and key informants/focus group discussion ii) Participatory mapping/seasonal calendars/time lines iii) Community meeting -1 and 2 (village level) iv) Community meeting-3 (*Beel* level-Annual planning meetings) v) Semi-structured interviews with fishers/*kua* owners/farmers/NGO and DoF personnel vi) Detailed Investigation on *kata* sanctuary vii) Validation of the research findings	a) August 1-7, 2005 b) August 2005 i) August 2005 ii) August-September 2005 iii) September 2005 iv) October 2005 v) August-November 2005 vi) October 2005 vii) November–December 2005
Phase 3. Write-up a) Site selection information b) Draft report on the preliminary information (habitat features, resource use/ fisheries problems/ migration, hydrology) c) Draft technical report	a) July 2005 b) August-November 2005 c)November-December 2005

Interviews were done using semi-structured discourse-type questionnaires. A set of questions was prepared to serve more as a guide than as a rigidly administered device. Questions were intended to stimulate discussion. The length of interviews ranged between 10-30 minutes, depending on the direction of the interviews as well as the knowledge of the individual interviewee. The willingness of participants and availability for the interview were carefully accommodated. Interviewees were given options with respect to whether or not they were interested in participating in an interview, and they were allowed to leave the interview in a situation even when part of interview questions were unanswered. In such case, a second person was invited to cover the unanswered questions.

Specific questionnaires were also used for individual specialists. It was observed that each interview had its own character and as such was allowed to unfold spontaneously. Interviews followed the format which most suited to the qualitative nature of my research. Interviewees included local fishers, community leaders, farmers, DoF officials, representatives from various NGOs involved in community based fisheries and natural resource management, and university professors.

A general understanding of the fisheries environment was also developed through a number of field visits and personal observations. In addition, a short case study was done on *kata* sanctuaries (brush piles), one of the key methods of habitat restoration and conservation. *Kata* sanctuaries are also used as a fishing aggregating device (FAD) in many places in Bangladesh. The *kata* study supplements the research by providing in-depth information with regards to local level habitat rehabilitation and conservation methods.

I would like to mention here that some PRA techniques overlapped with others. For example, when I was conducting focus group discussion and resource mapping exercises, the work related to time line analysis and a seasonal calendar was also completed. Similarly, much of the information related to key issues of habitat degradation was received from the participating key informant interviews, focus group discussion, and group meetings.

A total 57 people were interviewed both from community level at the *beel* and at the offices. This number excludes the number of participants in focus group discussions, participatory resource mapping exercises, and persons with whom I discussed various management issues informally. In selecting participants for semi-structured-interviews, emphasis was given to the traditional as well as elder fishers/community members living surrounding the beel who have direct involvement with the use of resources of the beel.

At the community level, a total of 40 people were interviewed, which comprise fishers and farmers and other stakeholders from three main villages called, *Mudipara* (N=15), *Masuria* (N=15) and *Jeolahati* (N=5*)* as well as five others that were chosen from other nearby villages, who occasionally fish but part the stakeholders of the broader basins.

At the office level, six government personnel (two from the local fisheries office and four from Dhaka office), five staff from three NGOs--GHARANI (N=2), PROSHIKA (N=2) and BRAC (N=1), and two university professors from the Department of Zoology, Dhaka University were interviewed. In addition, four core staff from Community-Based Fisheries Management Project Phase 2 (CBFM-2) of WorldFish Dhaka who has been engaged in habitat management program was also interviewed.

The third phase of the study included organizing data, pursuing analysis, verification of the data under analysis, and preparing a technical report. The collected data was verified by the village committee members, fishers, and key organizational representatives. The feedback from the verification succeeded in improving the authenticity of the research findings, as well as making the participants more comfortable in interviews at later dates. The raw data was arranged into several categories relevant to the objectives of the research. The data was categorized and the subsequent analysis formed the basis of the thesis accomplishment.

CHAPTER 2: LITERATURE REVIEW AND KNOWLEDGE OF FISHERS

My research tries to explore traditional fisher knowledge related to ecology of the floodplain ecosystem in Bangladesh and attempts to find a solution for conservation and management of inland freshwaters fisheries in degraded floodplains in Bangladesh. In this chapter, I highlight some of the recent thoughts and ideas related to key issues in management of freshwater and fish habitats in general, then a special focus is given to the Bangladesh situation. This chapter also discusses in-depth traditional ecological knowledge, with reference to fishers' knowledge in the understanding of the management relevance. Moreover, I attempted to understand the ways of how scientific knowledge and the traditional knowledge of fishers could be used in the management of inland fisheries; this chapter highlights some key perspectives related to the combination of the two knowledge systems.

2.1 Freshwater and fish habitat: management issues

Inland freshwaters comprise one of the major types of aquatic habitats. A freshwater habitat is important for various reasons; including that it supports human life in many ways; irrigation, transportation, and drinking water are provided. Furthermore, it is rich in aquatic life and 25% of faunal biodiversity occurs in inland freshwater systems covering an area of less then 1% of the earth surface (Mitland and Morgan 1997). Inland waters also the cheapest source of protein, and millions of people throughout the world maintain their livelihood depending on fish capture fisheries (FAO 2002). Despite their importance, freshwater habitats are seen as being prone to unprecedented levels of human and natural disturbance (Jackson and Marmulla 2001; Moyley and Sato 1994). Many aquatic habitats of the world, especially in the developing countries like Bangladesh, are now highly degraded and incapable of maintaining ecological functions (Ali and Ahmed 2001).

Habitat degradation has been identified as the major cause that results from malfunctioning of ecosystem processes, and half of the species losses directly related to the degradation of habitat (Primack 2002). There are many causes of ecological degradation in aquatic environment e.g. silt deposition in waterways, dam construction (for both hydroelectric and irrigation schemes), embankments for flood protection, encroachment and reclamation, and the conversion of aquatic habitats into agricultural land. Moreover, introduction of exotic species, uncontrolled harvest, and water pollution also greatly responsible for habitat degradation (Canadian Wildlife Service and Canadian Wildlife Federation 2003). Though both aquatic and terrestrial habitats are undergoing degradation, the severity of loss is more evident in freshwater systems, thereby negatively impacting the livelihoods of people dependent upon ecosystem integrity and natural productivity of the freshwater systems. Moreover, the degradation process in aquatic habitats is not similar to terrestrial processes as deforestation resulting in erosion in uplands watersheds increases siltation to river beds and similarly agrochemicals leach into waterways with residual toxic effects.

From a human perspective, fisheries are one of the highest ecosystem services. But freshwater fisheries are in threat for many reasons. According to Bart (2002), upstream siltation reduces river depth and discharge, thereby impairing feeding, growth and maturation of stream fish. Upstream siltation also obstructs movement essential for completing the life cycles of migratory species.

There are two contributors to the processes of habitat degradation: anthropogenic and natural. With respect to severity, human intervention in ecosystem degradation is more extreme, especially in a country like Bangladesh (Minkin and Boyce 1994). In a floodplain habitat the construction of embankments and nominal improvements to drainage tend to sharply constrict fish habitats. Dam construction radically alters stream hydrology, impacting ecosystems both upstream and downstream of the dam itself.

Clifford (2001) argued that the manipulation of the physical environments in the name of "controlling" them, has now reached a level equally threatening to the livelihood support functions of the environment and to the integrity of ecosystem processes. This can be seen as the outcome of the overconfidence of 19th and 20th century engineers and hydrologists in their approach to managing the physical environment, with their world-wide legacy of dams and embankments. We can now see the severe consequences to aquatic environments almost everywhere (Warren and French 2001).

However, the "hard-engineering" mindset, which has ignored ecosystem integrity, has now been somewhat supplanted by a more modern concept of "ecological engineering" for habitat remediation and restoration, intended to at least partially mitigate the deleterious effects of past practices (Warren and French 2001). Despite the potential convergence of ecological science and engineering practice, incorporation of conservation priorities is still at a level inadequate to achieve significant protection of natural systems that are subject to engineered improvements (Grumbine 1994; Smokoroski et al. 1998).

We are beginning to see the emergence of "eco-friendly" engineering: designs which are demonstrably practical and economic yet produce the desired ecological outcomes (pers. comm. Munir Ahmed, Fisheries Consultant to the Monu River Fish Pass program in Northeastern Bangladesh).

It is even more distinct that successful aquatic environment planning and conservation demand an aggregation of viewpoints and expertise which includes a range of bio-physical and social scientists, as well as local knowledge from local stakeholders (Clifford 2001). It also implies an integrated and multi-purpose approach towards achieving the objectives of participant- based natural habitat management.

According to Clifford (2001), the historical river uses and associated intervention/management has been characterized by the following themes:

- Engineering control and regulation
- Preservation and control of natural environment
- Restoration of the degraded environment

However, especially in the developing countries, anthropogenic impacts on the aquatic environment have rapidly increased both in scale and complexity. Similarly, the adoption of ecological conservation objectives is almost non-existent. Given the apparent inadequacy of the present environmental management as well as present day evolution of participatory environmental management trends, achieving ecological conservation seem more and more contingent upon non-technical social inputs (Clifford 2001).

There is no doubt that there is a growing interest in the sustainable management of habitats towards ensuring ecological integrity and conserving existing biodiversity. Since the 1980s, environmental conservation has been recognized as amongst the primary challenges of our time, as evidenced by the unprecedented "Earth Summit": the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, in 1992 (UNEP 1992).

However, at the present time, various efforts are underway locally and globally to protect natural habitats (Saunders 2001; Clifford 2001). Scientific and management level approaches include the creation and conservation of formal protected areas, the restoration of degraded habitats, the creation of new habitats as mitigation measures, and the removal of existing dams from certain water courses (Smokoroski et al.1998; Clifford 2001). But too often such solutions fail to achieve the expected outcomes for many reasons, and such programs, when seriously scrutinized, have been shown to be highly cost-ineffective. In some cases, the level of ecological degradation is so intense that effort to revert it is almost not feasible. According to Berkes et al. (2001) ecological restoration is least plausible where waterways and wetlands have been filled and reclaimed for agriculture, or where extensive terrestrial development has already been accomplished.

There are, nevertheless, proven simple methodologies for creating and enhancing aquatic systems (Welcomme 2002; Berkes et al. 2001). Many of these, for example brush pile fisheries in Asian rivers (known as *kata* in Bangladesh), have traditionally been utilized by small-scale fishers around the world. Such knowledge and such methodologies sometimes serve as alternative and cost effective approaches to aquatic resources management in place of, or in parallel with more conventional conservation practices.

2. 2 Importance of fishers' knowledge

In recent years, there has been a growing awareness that the conventional approach to managing fisheries is insufficient. It is being recognized that sustainable use of the world's living aquatic resources can only be achieved if both the impacts of the ecosystem on the living resources and the impacts of the fishing on the ecosystem are explicitly identified and, as far as possible, understood (FAO 2002). It is also being formally acknowledged that fishers are an integral part of the ecosystem and that their knowledge must be acknowledged to achieve wellbeing of both ecosystem and human (Neis et al. 1996).

Knowledge is an important tool for local communities in maintaining their livelihoods and for the governments to manage resources. At the local level, effective management is contingent on accurate information about biological components, threats to habitats, current condition, change in condition, and the socioeconomic factors of the surrounding communities (Burke et al. 2002). In the socio-economic context, fishers' knowledge is seen in all steps of fish production, harvesting, handling or processing, marketing and consumption. Similarly, in the ecological context, fishers have diversified knowledge about fisheries resources such as fish habitat, bottom features, water current, nature and scales of fish aggregation and abundance and conservation of biodiversity (Bergmann et al. 2004), location of breeding ground and migration (Poulsen 2001) and feeding and breeding biology of riverine fish (Faulkner et al. 2001). This knowledge is gained while fishers have been living and working in aquatic environments and fishers have been using the resources for their livelihood (Johannes et al. 2000; Bergmann et al. 2004). In general, a little of this information has been used within scientific study relative to what is available, or to what might be used (Berkes 1999; Pinkerton 1994).

Historically, due to inadequate information on the biology of fish, migratory behaviors, habitats of fish and other socioeconomic data needed for addressing various issues such as conflict resolution, setting regulation, establishing marine protected areas, the management of the fisheries resources remains problematic. On the other hand, there exists an immense storage of local knowledge and experience with the people who have been historically maintaining a livelihood dependent on fisheries. Freeman (1992) argued that the value of this human archival knowledge in scientific research and management and conservation has not been recognized before. But there has been growing interest in using local knowledge for achieving detailed ecological as well as management support, in development and implementing management strategies and decision-making processes. This change is partly due to indigenous people' rights and the general realization of the limits of conventional centralized management strategies and information collection techniques (Johnson 1992; Bao et al. 2001).

There are specific examples where fishers' knowledge has immensely contributed management, research and conservation. In a common pool resource, local fisheries knowledge helps to create decision-making rules related to management, exclusion, and alienation rights (Thé and Nordi 2001). Local ecological knowledge helps the fishermen identify the most productive fishing spots and are instrumental in determining the limits of the fishing area; maintaining fisheries yield and providing the basis for institutional rules regulating the spatial and temporal limitations for each users and helping with the conservation of fish *(ibid).*

Information possessed by fishers can be used to monitor stocks and physical environments, provide biological and technical data, and provide contextual information for management purposes. Fishers have the knowledge on how the stocks have reduced (this research and my previous investigations related to collection of data when working in open water fish monitoring program). More importantly, fishers are aware of contextual information useful in interpreting landings, biological and catch per unit effort data, information useful in understanding and assessing fisheries data (Grant and Berkes 2004).

Fishers can provide vital information in case of studies of migratory fish and related biological studies. Studies reveal that the current knowledge of tropical floodplain fisheries is scant and they are confined only to South Asia and Africa (Welcomme 1985; Bao et al. 2001). While studying Mekong river fish biology, Bao et al. (2001) pointed out that there is no detailed study on tropical floodplain fisheries, and that the ecological information of most

Asian rivers and fisheries are fragmentary. Bao et al. argued that the studies on fish migration in rivers have traditionally focused on limited number of species and have been done using complex, as well as expensive, methods such as tagging. In their research, it was pointed out that in case of third world countries, meeting the costs related to such experiments is not possible and with little exceptions, this type of sophisticated experiment has produced limited information regarding to multi-species fisheries. There is, however, immense storage of knowledge and experience in many floodplain fisheries with the traditional fishers. This knowledge can be use as alternative for study of fish biology.

To aid conservation and restoration efforts, comprehensive data and information on various aspects of fish biology such as population dynamics, management, hatcheries, water quality, and aquatic habitat and ecosystems are needed (FARN 2004). Very often, collection of detailed data is not possible because of time constraints and also the need for huge money involvement. In such cases, fisher knowledge can serve as an alternative source of information and can help sustainable management of fisheries resources.

2.3 The nature of traditional knowledge

Like other developing countries, Bangladesh has attempted to ensure fisheries development in a sustainable way and but has not properly applied the local ecological knowledge to resource management (Rahman and Minkin 2003; Minkin and Boyce 2004; Sillitoe 2000). However, there is a move towards using traditional ecological knowledge in recent community-based fisheries management projects of Bangladesh (MACH 2003; WFC 2004). Therefore, a brief discussion on traditional ecological knowledge could provide a better understanding for users ranging from scientists and managers, with respect to the underlying themes of traditional ecological knowledge and its relevance to management.

Keeping above issues mind and having scopes of using traditional ecological knowledge in the management of fisheries and conservation of fish habitats, I have tried to theorize some perspectives of traditional knowledge and definitions regarding it. I plan to define key terms related to traditional ecological knowledge by reviewing the available literature and creating a characterization of such knowledge systems.

Many studies revealed that so far there is no universally accepted definition of traditional ecological knowledge (Berkes 1999; Grenier 1998) and the complexities of defining traditional ecological knowledge lie in the ambiguity of the words "traditional" and "ecological". Berkes (1999) in his pioneering book *Sacred Ecology*, outlined the terms regarding traditional knowledge as follows:

1. **Traditional Ecological Knowledge**: A cumulative body of knowledge, practice, and belief, evolving by adaptive processes; it is handed down through generations by cultural transmission. It is about the relationship of living beings (including humans) with one another and with their environment. It is also mentioned that traditional ecological knowledge is both cumulative and dynamic, building on experience and adapting to changes. It deals with local ways of knowing and holistic in nature, thus helping to eliminate shortcomings of the continual development approaches and it provides supports towards political and economic gain of the local people.
2. **Local Knowledge:** Recent practical knowledge with short history can simply be called local knowledge. Such knowledge does not have multigenerational records.
3. **Indigenous Knowledge:** Traditional or local knowledge held by an indigenous group which is unique to a given culture or society.

According to Louise Grenier (1998) indigenous knowledge refers to the unique, traditional and local knowledge existing within, and developed around, the specific condition of women and men who are indigenous to a particular geographic area. Indigenous knowledge is parochial, confined to a small area, limited to what people can sense, observe and comprehend, using their own terms and concepts. Indigenous knowledge also referred to as "traditional" or "local" knowledge, as it is embedded in the community and is unique to a given culture, location or society (*Ibid*).

Other terms concerning indigenous knowledge and traditional knowledge are: ethno-science, local knowledge, folk-taxonomy and folk-biology, and local people's knowledge. In present development discourse, many scholars are comfortable with using traditional knowledge as a pragmatic ground for solving the complex problems with respect to resources management (Dewalt 1994; Warren and French 2001; Sillitoe 2000; Warren et al. 1999). In a broader sense, traditional knowledge also refers to a large body of knowledge, and skill that has been developed outside the formal education system and enabling a community to survive. It is recognized that indigenous knowledge is part of people's memories and expressed in story telling (Simpson 1999) and by nature, it is dynamic; there is a room for incorporation of new knowledge to adapt to a new situation.

Since traditional ecological knowledge is encompassed in indigenous knowledge, considering the more ecological perspectives (Dudgeon and Berkes 2003; Korten and Uphoff 1981), this paper both terms will be used interchangeably especially when comparing with other knowledge (Western science knowledge). In a broader sense, the term indigenous knowledge would mostly be considered to prevent clumsiness and promote fluency of reading. Additionally, there are some subtle distinctions between traditional ecological knowledge and indigenous knowledge (Dudgeon and Berkes 2003) which are not the part of the discussion.

Historically, traditional knowledge was a part of problem solving for the local people and has used by the local people for management of their resources on a sustainable basis (Khan 2000). In the 1950s and 1960s, theorists of the developmental philosophy considered indigenous and traditional knowledge as inefficient, inferior and an obstacle to development (Agarwal 1995). By the beginning of the early 1980s, for the first time the non-aboriginal/Western scientists paid attention to examining and incorporating knowledge of local traditional peoples, in order to obtain a greater understanding of environment (Berkes 1999). Now, throughout the world, there is a growing interest in using such knowledge in resource management and environmental impact assessment (Berkes 1999; Freeman and Carbyn 1988 cited in Gallagher 2001) and this is often viewed as the latest and best strategy in the old fight against hunger, poverty and failure in development (Richard 1989; Scoones et al. 1992). Such an approach recognizes that experts could learn and benefit from knowledge of people who live and work in the area of natural resources.

The dominance of western knowledge systems has largely led to a prevailing situation in which indigenous knowledge is often ignored. Indigenous knowledge is closely related to survival and subsistence of the local people and it helps for local level decision making regarding food, security, health, education, natural resource management and many other community based activities (UNESCO 2004). Specific to fisheries, this knowledge may be about fish ecology, climate, weather, technology, legal or regulatory, biology, ecology and institutional management systems (Berkes et al. 2001). There are wider debates on indigenous knowledge versus western science-based techno-ecological knowledge. In the Table-3, I have summarized some of the common differences between indigenous knowledge and western-based scientific knowledge.

Table 3. Common differences between local indigenous knowledge and western science

Property for comparison	Local indigenous knowledge	Western scientific knowledge
Relationship	Subordinate	Dominant
Communication	Oral, story telling, singing, dance	Literate
Dominant mode of thinking	Intuitive, holistic Mind and matter considered together	Analytical, reductionist Mind reduced to matter
Instruction	Learned through observation or hands-on experience (Adaptive learning)	Got taught and learned in a situation usually separated from the applied context. Adaptive learning mostly absent.
Effectiveness	Slow, inconclusive	Fast, conclusive
Data creation	Based on personal observations, trial and error, and synthesis of facts	Based on experimentation and systematic, deliberate accumulation of facts
Data type	Qualitative	Quantitative
Data generation	User involved	Specialized cadre of researchers
Explanation	Spiritual, moral	Hypothesis, laws, mechanistic, value free
Biological Classification	Ecological	Generic and hierarchical
Nature	Viewed as subject	Viewed as object
Complexities	Table continued to next page Capable of dealing with complex social ecological issues through experience and multi-disciplinary focus	Often fails to handle complexity because discipline focused views
Situation	Local context	Institution based, de-contextualized
Transmission	Oral or cultural means of communication and multi-generational	Limited to one-generation through one-way using powerful media

(Source: Gadgil et al. 2003; Berkes 1999; Agarwal 1995; Wolfe et al. 1992).

According to Berkes (1999), there are both similarities and dissimilarities between indigenous and western knowledge, and both are the result of the same general intellectual process of creating order out of disorder. At the same time, the two kinds of knowledge are fundamentally different as the physical world is approached from different ends in the two cases; one is supremely concrete, and the other is supremely abstract (Levi-Stauss 1966).

According to Berkes (1999), the ideological debates are not sharply divided; rather they hold a reductionist view that tends to exaggerate the differences.

From the Table 3 discussion and the context revealed here, it is evident that there is a substantial difference between indigenous knowledge and western knowledge. However, moving beyond debating on "superiority" or "inferiority" becomes vital and such debating has a little practical application when considering its own dynamics with respect to problem solving especially to the modern days' complex nature of resources management. At this stage, researching on how traditional ecological knowledge could be used as an essential component for conservation and development is worthwhile.

2.4 Combining different kinds of knowledge in resource management policy

All over the world openwater fisheries, inland and marine, have been facing various problems in the context of resources depletion. The issues are mostly related to multifaceted management problems and consisting of institutional, social, cultural, economic and ecological ones (FAO 2002). It is simply evident that the solution to a number of problems in isolation of a particular resource is virtually impossible and this is why there is a need for a system approach to management. Ludwig (2001) urged it is too difficult to separate the fisheries issue of management from the issue of underlying values, equity and social justice, and providing a simple solution.

Knowledge is the basic tool both for scientists and resource users and that in turn leads to a solution for management. For solving problems related to natural resource management various efforts are underway, giving out a number of concepts (Berkes 2004; Holling 2001; Holling and Meffe 1996; Kapoor 2001; Morgerum, 2001; Neis et al. 2001) which help scientists and the resource users to reach a common goal in managing natural resources in a sustainable way providing long term benefits for society. A combination of the two knowledge systems could provide a better understanding in management systems. Before thinking of combining two knowledge systems, we would have to have a clear understanding about the properties and the debates regarding both knowledge systems.

According to Ludwig (2001), conventional sciences have different ways of problem solving which are not similar to the traditional way. He pointed out that science has three types of problem-solving approaches:

1. It does not act before a crisis is already created and affect the society, nature etc. and thus it's devoid of the idea of prevention is better than cure
2. It takes advantage of the disorder in order to incorporate interventions into systems. This turning point creates a harmony to a crisis, as disorder often occur in the aftermath of a crisis
3. The third approach regards any information with skepticism which has been received from sources other than scientific approach.

Additionally, scientists are not receptive to accumulate the value of traditional ecological knowledge as a source of information (Kapoor 2001). Very often there is a bias to the government bodies and a tendency to demonstrate the paternal nature of the state, where they hold the idea that state is best to choose what is the best for the society (Kapoor 2001). Their view is that the "public is an obstacle to development targeted for better resource management". They very often ignore the fact that resource users have much more understanding of resources than the managers or scientists as the local people experience it at their door-front. As a result, science-based solution of a natural resources management becomes ineffective.

Natural resources management options are always precluded by some difficulties and as if, it is not easily solvable. Ludwig (2001) defined such a nearly unsolvable problem as a "wicked problem," which is characterized by no definitive formulation, no stopping rule or no tested methods for solution as the problems are social or economical and biological and enrooted in different scales.

Science often tries to handle such problems in an analytical way. That is it breaks the problem into its parts and tries to solve them separately (Kapoor 2001). The approach relies heavily on the idea that an unbiased researcher is readily capable to answer all the questions related to natural resources management. There is a strong downside to this approach as it nullifies the human factors from environment and holds the idea that there is no consequence from resource exploitation, and also that the top down approach of resource management is most appropriate (Kapoor 2001). The approach eventually supports the Hardin's concept (1968) of "tragedy of the commons" where there is a strong emphasis to put an authoritative management of common pool resources. In reality, the idea of separation of human from nature seems to be not true as humans are not independent of the nature.

Giving the shortfalls of the conventional science-based solution, increasingly, the published scientific literature, workshops, and conferences reflect the growing awareness that there is a legitimate form of environmental expertise known as traditional ecological knowledge (Johannes et al. 2000). Johannes and others also pointed out that this knowledge is ecological in nature and contains many interacting species of animals and plants and the determinative role played by certain key biological and physical parameters in influencing the behavior of the total biotic community. It is important to note that such traditional ecological knowledge has been found to have management relevance and can serve as a complement to solve complex natural resources management problems (Berkes 1989; Freeman et al.1991; Kelso and Wooley 1996)

The contextual ground of such views indicates a holistic nature of research and management where local peoples and their knowledge would contribute in natural resources management. This in turn refers also to bringing local knowledge to the premise of scientific management paradigms.

Grumbine (1994) pointed out ecosystem management as being part of a wider context of integration of scientific knowledge; of ecological relationships with complex sociopolitical thoughts that value framework towards the general goal of protecting ecosystem integrity on a long-term basis. Grumbine (1994) also added that the principles of ecosystem management are also very similar to that of collective/collaborative management and identifies that a wide range of methods including management and sharing of knowledge happen within hierarchical context, ecological integrity, participatory data collection, adaptive management cooperation between society and scientist are vital.

Throughout the world there is a trend in conservation and management to promote stewardship by actively incorporating local knowledge, building upon it and creating a multilateral cooperation among scientists, managers and stakeholders (Pretty and Smith 2004). A number of authors attempt to define such collaborative management based on numerous characteristics combining various theoretical frameworks. Ludwig (2001) states this type of management is a system of "direct participatory democracy". This statement promotes partial consensus on resource management decisions and holds the idea of participatory decision making based on collaboration. There are some opposed views regarding this idea. Kapoor (2001) pointed out that while consensus is important, single decision-making should be avoided, instead temporary or multiple consensuses are expected. For resource management, the collaborative process brings some mutual benefits for a wider community and includes reduced social and cultural impacts that certain management measures result in. Collaboration between various groups can result in economic benefits for the individuals. Another benefit of this process is that they often make management more effective, increase the acceptability and enhance understanding of natural and human systems and most importantly, established trust (Schusler et al. 2003). Collaborative process also helps develop environmental stewardship and puts in effort to create resource users where more responsible to manage and protect it (Mitchell 2002).

Though collaborative management shows potential benefits to natural resources management, it is also posed with some risk (Crotner et al. 1998). Monitoring, evaluation of objectives of resources management project and setting appropriate goals and processes all are needed to meet the needs and wants of stakeholders. Lack of commitment is also a great concern in this process. Without government commitment it is not possible to change programs, policies and actions which largely limit management options (Margerum 2001). Lack of commitment from the opposite side (i.e. stakeholders) can have just the same impact as that of government and thus should not be overlooked. In this situation, a combination of strategies would be followed rather than being confined to one set which covers a wide spectrum of societies. Managers and policy-makers must use the collaborative approach that allows full public participation throughout the whole process and consequently helps develop legislation and policy that promote economic and ecological sustainability (Slocombe and Dearden 2002).

Following the interest in combining two knowledge systems, there have also been rising concerns and skepticism regarding its conservation and monopoly of use respectively. Some authors have objected to the use of traditional knowledge as it is, in many cases, a part of spirituality/beliefs of the indigenous people and argued that traditional knowledge can not be interpreted from a western view point (Simpson 1999). Simpson (1999) also emphasized that science in using local knowledge outside the cultural context produces a skewed view of local knowledge.

Indigenous knowledge is sometimes framed into technological approaches and recently has been called "traditional technical knowledge" to distinguish it from the more culturally encompassing "indigenous knowledge". These have been used as two distinct approaches to study local knowledge of the environment (Dudgeon and Berkes 2003).

With respect of such dual uses of traditional knowledge, Sillitoe (2000) urged that

...the narrow notion of ITK, presenting it as culturally appropriate disembodied technical knowledge is dubious and it is doubly dubious to isolate technical from its cultural context and attempt to match it with western scientific concept. This approach may be termed as invasion of western knowledge into indigenous knowledge though claimed to act in the interests of locals, but certainly the status is different from a local viewpoint.

Conversely, scholars and scientists educated in western scientific ideology consciously or unconsciously subscribed to scientific paradigms rather than to other systems of knowledge such as traditional knowledge when involving them in resource management (Wolfe et al. 1992).

We understand that there is still a long way to go to find out the truth of two knowledge systems and try to link the two knowledge systems. However, we see from various recent studies that traditional ecological knowledge has been found to have management relevance, especially in regard to sustainable use of renewable resources (Berkes 1989; Freeman et al.

1991), which will be a significant prospect for modern day resource management. In addition, traditional knowledge is cost effective and offers sustainable survival strategies for poverty alleviation and rural development, and therefore needs to be documented and disseminated (Khan 2000). Bearing these thoughts in mind, it is expected that the researchers would search for a common ground of understanding and cooperation to decrease the cultural division for better management of the natural resources.

CHAPTER 3: PROFILES OF THE STUDY AREA

3.1 Defining the study area

The study area is a *beel* fisheries site of Bangladesh. It is one of the most important fisheries other than rivers and floodplains. The study area is situated in the Kaliakoir area of Bangladesh. Kaliakoir is a sub-district under Tangail district and is situated about 60 km northwest of Dhaka. Topographically, beels are a type of back swamps laid down away from natural levees. They are natural depressions of marshy characters representing perennial or seasonal water bodies and are found largely in the active or inactive flood plains zone of rivers. They are a fully rain fed waterbody and fill with water in monsoon months (May-December), but partly dry up winter and summer months (January-May). The fertility levels of the beels are very high, having extensive layers of sediments composed of organic matter. For this reason beel soil becomes darker in color and responsible for production of enormous natural food for fish and other aquatic organisms and *beel* soil makes attractive habitats for fish.

The natural fisheries of a beel are determined by the level of its connectivity to a larger sources of waters such as rivers. When a beel is connected to a river it exhibits a mixed typed of fisheries, composed of both lotic (fish found in stagnant waters) and lentic (fish found in running waters) species. When it is a closed waterbody, it possesses a very distinct fauna as compared to other open waterbodies. As the beels hold dynamic hydraulic features between dry and wet conditions according to season of the year, they experience a different degree of human interactions. For example, they served as an active area of common pool fisheries resource (active fishing grounds) during the period of inundation (June-December), or area of productive agricultural lands followed by dry periods (January-May). The *beels*, if permanently covered with water, remain uncultivated and are mostly used as a fisheries area, otherwise they are used as mono-culture area of rice. The latter types of beels are fully private properties with multiple ownership and very often conflicting with the fisheries development. The deeper *beels* are government property called as *jalmohal* and are part of the present revenue oriented fisheries management of Bangladesh. *Jalmohals* are periodically leased out to individuals or cooperatives that either stock them or use them as capture fisheries areas. The beel under the study was a seasonal floodplain beel and was not under *jalmohal* systems of Bangladesh.

3.2. Physical profile

The study area is situated in the Bonshi-Dhantara river basin of Kaliakoir thana of Gazipur district, Bangladesh (Fig.1); a part of sub-basin of greater Jamuna-Bansi Basin. The river Bansi runs through the north-east part of the beel and the Dhantara is through the southern part. In the past, both of the rivers were connected to the beel by two narrow canals called Haran Khali (situated at the northeast) and Jhat khali (situated in the south-west) respectively (Fig.1).The canals served as the major passages for replenishment of mature and juveniles fish to the beel. The gradual siltation in their courses and resulting changes due to filling the canal by soil for agricultural use, the links hardly facilitate fish migration. It was reported during the study that disturbance in the fish migration route has greatly changed the quality and quantity of the fish catch. Fishers and other community members feel that the fuller operation of the canal is vital for healthy production of fish in the beel.

According to the fishers, the beel has also been experiencing significant changes from other factors as well. The changes are both related to special and temporal nature of the land use in and around the beels as well as extensive human interventions in the beel bed. The peripheral shallow zones of the beel have been converted into homesteads and agricultural lands. In addition, the beel basin experiences land-filling to make it flood-free. As a result, there had been a significant change in the morphological feature of the beel. Fishers believed that this type of encroachment in the beel greatly modifies the fish habitats.

It was reported by the fishers that the beel water levels fluctuate significantly (between 0 and 3 m). But in some years, it may also dry up completely. These spatial variations bring opportunities for various kinds of uses for the beel bed. For example, in December-May when water from the beel area recedes, the shallow to medium-flooded areas of the beel are used for paddy cultivation. In addition, small natural levees in the beel bed are also used for cultivation of seasonal vegetables.

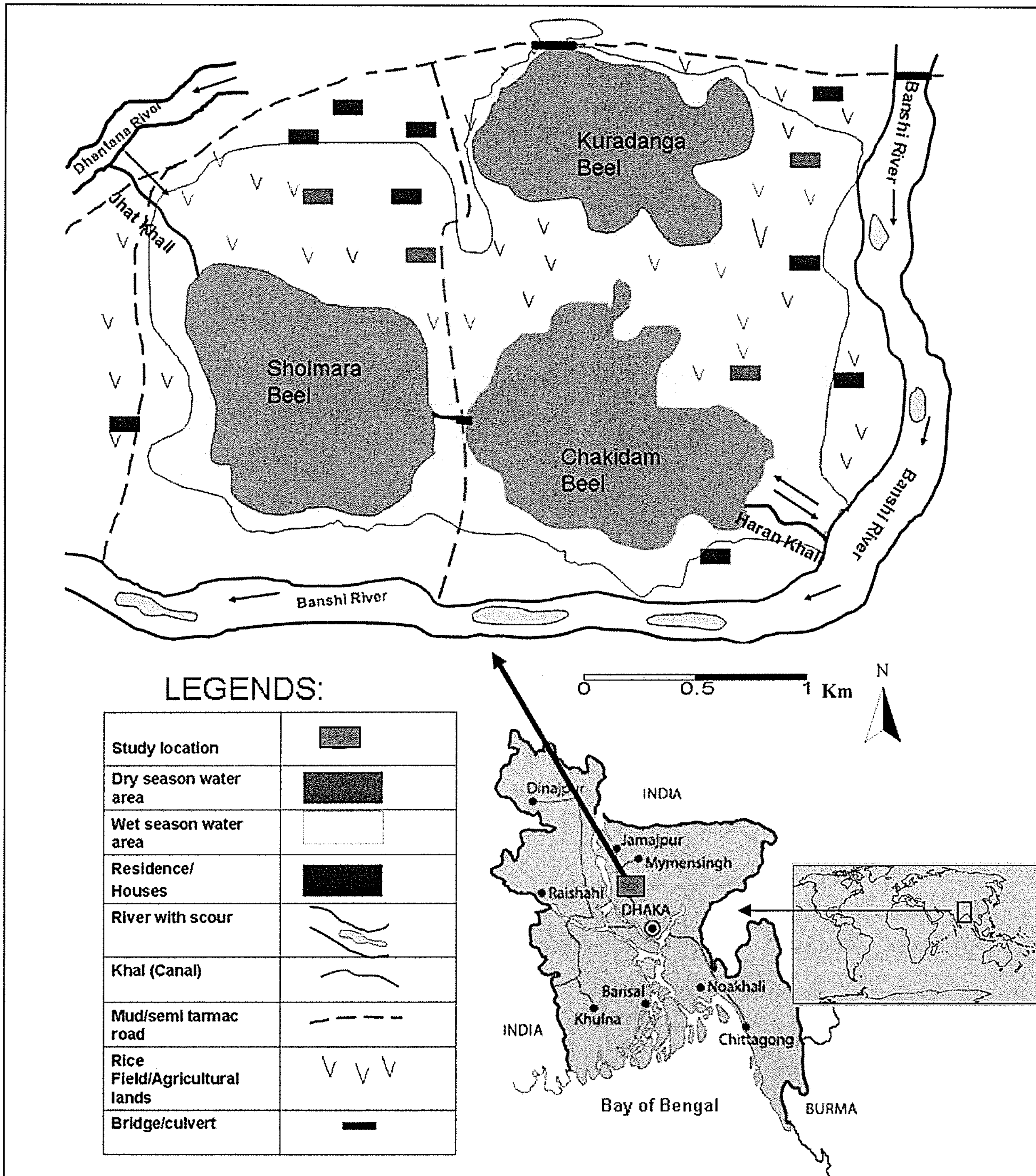

Figure 1. Sketch map of the study area

In extreme dry months (May-June), a small fraction of beel basin remains as a core area of the beel serving as fish habitats. When the beel area shrinks further, extensive fishing followed by low water levels occur. It brings various threats to fisheries such as harvesting of broods and disease infestation. Extreme dry years bring more areas under cultivation and intense agriculture takes place. Agricultural farming in *beel* beds is considered responsible for damaging rooted vegetations needed for fish survival when the area is submerged.

However, agriculture farming is one of the major livelihood incomes for people living surrounding beels while fishing is considered as a secondary source of income for the non-fishing community. During the field investigation, it was widely agreed by the non-fishing community that beel fish is needed for meeting their daily consumption as a cheap and nearby source. However, "fisheries" has quite a different meaning for community fishers who completely depend on fishing. To them fish is part of their culture and only source of livelihoods income. If the beel sustains, it helps maintain both their culture and livelihood. As a result, there was a mixed response among interest groups in how the beel habitats would be used for a variety of things including for fisheries or for agriculture.

Due to changes in the land use patterns, the beel has lost half of its original area (about 16 sq km). At the present, the beel divides into a scattered pool of waters during winter and dry months (December- June), (Figure 1), having an area of about one 1 sq km. According to fishers, previously the beel was a single entity. It is now divided into three different parts: (a) *Chakidam*, (b) *Kuradanga*, and (c) *Shoilmara.* Major causes of such division are: silt deposition and interventions in the beel bed i.e. construction of roads across the beel. The dissection of the beel due to the roads is very destructive. It has blocked waterways hampering dispersal of fish broods and juveniles during monsoon. This has reduced feeding, nursery and spawning grounds for the fish. There are three earthen roads in the beel basin (Figure 1). The earthen roads are not made with adequate culverts or bridges. As a result, they block the fish movement between beels and nearby floodplains.

Since 2003, the beel has been under a Community-Based Fisheries Management (CBFM) project implemented by the DoF, in collaboration with Gharani, (local NGO) with technical cooperation from the WorldFish Center. For a joint operation of management activities by the local NGO, the beel is called by an acronym *Chakusho* that takes the first syllable of the name of each beel.

3.3 Socio-economic profile of the study area

The study area is situated at Kaliakoir upozila of Gazipur district of northcentral Bangladesh. Three main villages--Basuria, Mudipara and Jeolahati under *Dal jora* union council--surround the beel. The WorldFish center Bangladesh conducted a survey in 2003 to understand the socioeconomic status of the area under the study. It revealed that there were 2325 households in the beel area. The sample survey of this study gave an account of 1323 households (Table 4). The households were surveyed based on stratified random sampling and were categorized into five groups based on the land-holdings, one of the best indicators to know the status of each household category. Table 4 shows number of samples drawn from each category by village and waterbody sections.

Table 4. Household categories in the study area

Section name of the beel	Village name	Total households (No)	Category				
			Category I (<.5 acre)	Category II (<.5 acre)	Category III (<5 acres)	Category IV (<5 acres)	Category V (>50 acres)
Chakidam	Jeolahati	387	37	44	18	116	172
Kuradanga	Mudipara	380	26	35		136	183
Shoilmara	Basuria	556	14	145		223	174
Total	12	1323	77	224	18	475	529

Note : I=Poor fisher, II=Poor non-fisher, III=Medium fisher, IV=Medium non-fisher, V=Better off (Source: WorldFish Center Household Survey 2003)

The sections were defined as Chakidam, Kuradanga and Shoilmara. The survey revealed that male members of the villages have a number of occupations such as farming, fishing or fish related business, day laborers, craftsmanship, potter, and livestock raiser. The females of the villages are mostly engaged in the household activities. The stakeholders of the beel comprise: land owners, small traders (engaged in selling fish or running stationery shop, potters etc), share-croppers, ditch owners and community leaders and country-boat owners.

Fishing is largely considered a male profession. Few women participate in fishing. They also do other jobs related to net repairing and fish processing. Farming is the main livelihood incomes for the landowners of the study area while fishing and pottery rank respectively second and third as a livelihood income for other stakeholders. Household comprising of teens, adults and elders are seen to catch fish. However, the rate of acceptance of fishing as a profession by younger generation is declining as they are more interested in seeking jobs outside their community. This trend does not imply that fisheries are not important to them. They are found to be interested in participating general meetings on fisheries management and helping in building awareness amongst local community with respect to conservation and management.

In rural Bangladesh, possession of land is considered the most important indicator of the economic status of a household. It is evident from the survey result that a big group of people possess a very minimum amount of land. It is estimated that the yearly income per poor household ranges from BDT 30,300-40,000/- (equivalent to US $ 450-550). In this sense, stakeholders are mostly poor with minimum options for livelihoods income. The survey does not show the exact number of community fishers' households participating in fishing in the beels. It does not show much information about the stakeholders either. However, a reconnaissance survey during the study shows that about 350 households (15%) from community fishers have been living surrounding the beels and they are fully or partially dependent on the fishing in different sections of the beel.

Traditionally, the fishing profession in Bangladesh has been dominated by a lower caste Hindu community called *Jele.* (In contemporary Bangladeshi usage, this term is often used to mean professional fishers in general). In recent times, poor people from both Muslim and Hindu communities have entered into the fishing profession. Among the Hindu fishers, the most dominant groups are *bongsi* and *koiborto*. In the case of Muslim community, such classification does not exist. In addition to the permanent fishers (mostly *jele*), marginal farmers also participated in seasonal fishing on a commercial basis. Seasonal fishers either engage them as day laborers in big fishing units such as *ber jal* or low-cost individually operated gear (e.g., scoop net *Thela jal,* and traps *Polo, basun*). Moreover, a big group of low income households also participate in intermittent fishing to meet their household protein needs. As such, fishing has been an important resource for a wide range of stakeholders.

The landowners are the dominant groups in stakeholders. Cultivation of rice in the *beel* bed is their major source of income. Often they are not directly involved in the rice farming; rather they prefer managing their lands through a sharecropping system. The lands under sharecropping systems are owned by 11 local rice farmers who live in cities such as Dhaka. It is estimated that 50% of the cultivable lands in the beel area are under a sharecropping system. To the landowners and sharecroppers, cultivation of rich becomes first choice over any other achievable benefit from the beel. The excessive reliance on rice farming has perhaps become one of the major drivers behind fish habitat degradation. However, with the increasing demand of fish, landowners also feel that creation of good fish habitats can help fish production by giving dual benefits from the same land. They also feel that production of fish locally will increase the fish availability in the local markets and that will benefit landowners and their neighbors in having fresh fish.

Permanent fishers are all landless stakeholders in the beel area. They enjoy open-access fishing on the private lands for at least six to seven months (June-November). On the onset of the dry season (November onward), only *kuas* (ditches constructed in the beel basin supported by bush piles and owned by the landowners) hold water where fishing is restricted. At that time, regular fishing is suspended and fishers either move to other waterbodies or become unemployed.

The study area is situated in the close vicinity to the Dhaka-Rangpur Highway (about 15 km away from the highway). A feeder road connects the beel to the highway. Due to good road communication, fish price of the beel area is higher in comparison to distant places. Although fishers are getting higher prices from their catches, their net income has significantly declined as the volume of fish catch has declined greatly. Fishers daily income ranges from Tk. 50-70/- ($ 0.75-1:00) per day. There are 6-7 fish traders who collect the fish directly from fishing spots and transport them to cities such as Dhaka.

3.4 Major issues and status of fisheries management in the study area

Traditionally, the fisheries of the study area have been open access properties. As a result, indiscriminate use of gears and overexploitation has been common in the fisheries in the study area. Overexploitation has greatly reduced the fish production of the study area. This is also augmented by siltation the habitat degradation in the migratory paths i.e. the canals (see Figure 1), as well as conversion of beel bed into agricultural lands. Both of the causes have led to the depletion of the resource. By consulting fishers (permanent and subsistence fishers) and other stakeholders (landowners, fishtradres and local community representatives/political leaders and fisheries managers) in the study area, it was evident that there was a lack of implementation of the existing Fish Act and regulations. Due to high population density in the study area and scarcity of the resources such as fish there have been various conflicts among resource users. There are conflicts of small versus larger gear owners, community fishers versus non-fishers, and fishers versus land owners. In the wake of scarce resources and conflicts, many community fishers have left their traditional professions and have switched to other professions like fish-trading/marketing or running small business and even farming. Professional fishers (both from rich and poor groups) and the part-time fishers participate in regular fishing. They use various types of gear such as gill nets, traps, seine nets, and long lines. The non-fishers who own the lands in the beel have sole access to brush-pile fishing which is contained in small to medium-sized submerged ditches are situated comparatively in the deeper region of the beel (Figure 2).

Figure 2. View of brush pile with water hyacinth growing on submerged tree branches

There are 56 ditches locally called *kua*. The term, *kua,* also refers to a localized version of brush pile fishery in ponds where tree branches and bamboos are staked underwater to provide cover and food for fish. For detailed information on kua, see section 5.1.4 of this thesis.

Physiologically and geographically, the location of the beel is important for providing good fishing ground. The eastern canal, called *Haran Khali* is now functional and serves as the major pathway to facilitate migration of riverine fish to the beel thus helping production. The southern canal, called *Jhat Khali*, which is almost dead. As a result *Haran Khali* has been the only important link for fish migration. Unfortunately, this canal is also experiencing severe silt deposition in its waterway. The canal is threatened by the encroachment of landfill used to prevent agricultural land erosion. According to fishers, for maintaining healthy fisheries, re-excavation is needed. The eastern canal (*Haran Khali*) is an important fishing channel. The beel, along with the canal, provide good fishing opportunity especially during water recession phase (November-December). Fishers catch fish either individually or in groups depending on the mode of operation of the gear. When flood waters recede in December and onwards, fish start to migrate though the narrow *Haran Khali* to the big river systems (Figure 3) and the area turned into good fishing spot.

Figure 3. View of *Haran Khali* canal (width about 3 m)

The seasonal fishing in the canal is very transient and is locally called *Jo*. During *Jo* individual is not allowed in the canal. But a single fishing unit (mostly a unit from bag-net) unit is collectively assigned by the villagers around the waterbody to fish in the canal. This unit puts out a bag-net, blocking the migration route of the fish. Fishers share the catch among the community. The bag-net owner also gets his own share from the catch. Ninety percent of the catch of the assigned fishers is distributed among the villagers. It was reported during the study that the fishing in the canal by using set-bag net is highly destructive, especially during migration time (June-August) as it catches broods entering the beels. Fishers informed me that migration is also hindered by the canal as it is too narrow and shallow.

During the study period, government intervention in respect to managing the fisheries of the study area was not evident. According to the Fish Conservation and Protection Act of 1950, fisheries officers are responsible to prohibit destructive fishing like catching of carp juveniles and enforcing ban on gill nets during spawning season (May-July). Fishers reported that the enforcement is very weak and fisheries officers are seldom seen visiting the area. As a result, fish production from the study area is declining.

Since 2004, a local NGO called *Gharani*, is implementing a community-based fisheries management project (CBFM), in collaboration with the WorldFish Center, for sustainable management of fisheries and equitable distribution of natural fish catch from the beel. They have been supporting various income generating activities such as small trades, craft making and the raising of poultry and livestock to reduce fishing pressure and arrange training for capacity building. This initiative brings all stakeholders concerned into the decision making process of the beel management. There is a central committee called Beel Management Committee (BMC) and 11 village-based subcommittees. These committees take part in decision-making related to conservation and they help with conflict resolution related to beel fisheries. They also take part in different management planning meetings related to plantation, social welfare, road maintenance, poverty alleviation and rural education so that sustainable and comprehensive management can be ensured. The local NGO supports the above mentioned activities. Fishers are optimistic about the positive impact of fisheries conservation measures. Fishers, with the help of the project support, have developed their own fisheries management plans and conservation measures such as prohibiting use of destructive gear and observance of a closed season during fish spawning. They have also constructed two fish sanctuaries which have been managed by the community participants. BMC is partially successful in motivating the fishers' community to comply with locally developed conservation options; however, like in many other open water fisheries in Bangladesh, the issue of improvement of the overall habitat degradation has not been a success. For example, the fish migrations routes are either silted or under the control of various interest groups.

CHAPTER 4: MAJOR FINDINGS

4.0 Fishers ecological knowledge concerning fish habitats

The data concerning local knowledge is based on interviews with people of various professions/stakeholders including fishers, farmers, ditch owners, fish-traders, community-leaders, landowners, local community representatives/political leaders and fisheries managers. Indigenous knowledge was also gathered during participation of key informants/focus group discussions, mapping exercises and community meetings regarding beels. By analyzing the data gathered it was revealed that fishers have diversified knowledge with regard to fish habitats: types of fish habitats, habitat preference, hydrology and water cycle, fishing arrangements. It was also observed that fishers are aware of various changes happening in the beel basins and the impacts of such changes with respect to degradations of fish habitats, fish production, fish biodiversity and rural livelihoods. The knowledge that has been accumulated over the century emphasizes their awareness about the aquatic environment and fish habitats. Fishers also have historical perspective as to how the physical structure of the fish habitats have been degraded by the increasing demand for homesteads and agricultural farming. An account of their knowledge is provided in the following sections.

4.1 Fishers knowledge: fish habitats classification

Fishers and other community members around the waterbody possess adequate knowledge with respect to fish habitats that could be used to further define the habitats. It was observed that fishers and local people define the beel habitats mainly on the basis of water depth, colors, water movements, location of the water body and its contribution to fish catch and habitat supports for fish. Table 5 outlines how local fishers/community classified the fish habitats in the study area. The local level classification of the waterbody by the fishers relates to the importance of various types of habitats used by the fish in their various life stages, and also to its contribution to the feeding habits of fish. From their observation it is evident that different zones of a waterbody have different roles with respect to fisheries.

Fishers informed me during the interviews that the particular nature of water affects fish differently. *Kala pani* (clean water) is good for the production of *naola* and *puti* fish (mostly the carps and cyprinids). On the other hand, *ghola pani* (turbid water) helps to grow small shrimp. Fishers pointed out that turbid water did not enter the *beel* in 2005, so the production of shrimp was lower. This refers to the phenomenon that a lower load of nutrients persist in clean water. According to fishers, water quality is one of the big factors for survival of fish. In the polluted waters only air breathing fish (e.g. *taki* and *shing* fish) can survive. Fish available in polluted waters are very often unpopular with local consumers.

Table. 5 Local level classification of waterbody and their uses by fish

Zone	Local Name	Uses to fisheries
Shallow water	*Chara*	Egg laying and foraging area of fish. Key habitats for small indigenous fish
Deep water	*Goheen pani*	Shelter of larger fish. Dry season fish refuge.
Turbid water	*Ghola pani*	Impedes underwater vegetation growth. It also helps to grow natural feed for fish while carrying nutrients and silt deposition in beel bed. Many fishers believe that highly turbid water is a limiting factor for natural stocks. Fishers' information is that if there are more turbid water, growth of small shrimp will increase.
Clean water	*Saf pani/kala pani*	Contains fewer nutrients. Help to produce certain species such as small minnows.
Arrival of water	*Bonna*	Carries silt, helps natural fertilization of lands, helps entrance of fish broods into beel and fish production increases.
Recession of water	*Pani mela kora*	Movement of water from beel to downstream rivers. According to fishers it also carries fish to deeper zones of rivers where there is no access to fishing. Water recession is followed by high fish catch.
Downstream area of rivers	*Bhati*	Place of key fish refuge in dry season. Over-wintering habitats
Upstream area	*Ujan*	Places of key fish spawning center especially for carp. Also serves as key fish habitat in dry season if the area possess river scours
Cove	*Ghona*	Shallow zones of a beels/river forming key habitat for carnivores
Deeper parts of river (river scours)	*Doa/Doab*	Key dry season refuge for brood fish. Fishers believe that conservation of such areas is very important for long term benefits to fisheries

(Note: Based on a group meeting composed of fishers and community members dated September 8th 2005)

4.2 Fishers knowledge: fish behavior and interaction to habitats

The study discovered a wide range of information from fishers related to fish behavior. The information encompasses fish migration, growth and spawning techniques and biodiversity. Fishers informed me that there are two types of *beels,* they are either connected to rivers or they are not. The connectivity among waterbodies influences the diversity of fish in a beel. In general, when a beel is connected to the river it exhibits higher fish diversity in comparison to beels with no connection. According to fishers, the shallow area *beels* and the deeper areas (river scours) and the closed and opened fish habitats provide various components needed for completion of the life cycle of fish (e.g. feeding and breeding grounds) and they all help in meeting good production of natural fish (Table 6).

Table 6. Habitat preference by major fish groups

Fish groups	Preferred habitats
Pona (Hatchlings)	Shallow beel or flooded lands
Rui related species/*rita*	Rivers
Boal/ayre/gozar/tengra	Rivers and beels. *Boal* enters beels for spawning and deeper beels serve as their habitats
Putti/chanda/mola/drakina	*Beel*/dead rivers/canals, ditches.
Koi/shing/magur/shole/bheda	Shallow beels with vegetation
Tengra/chnada/baims	Shallow zones of rivers and beels
Taki/raga	Edge of the beel with vegetation

(*Source: Based on group meetings and semi-structured interviews)*

Different fish have different habitats. *Boal* are big catfish that normally come to breed in shallow waters such as in beels or canals, but spend most of their life in deeper areas such as rivers. Very often they enter shallow areas of the same waterbody where they live in search of prey. On the other hand, small fish such as *darkina, puti,* and *mola* (small minnow) always prefer shallow and clean water for their growth and survival. Many small fish such as small cyprinids like *mola, dhela,* and *darkina* are local breeders. They use submerged vegetation for egg-laying as do many fish such as small shrimp stick their eggs to submerged leafy vegetation.

In addition to knowledge regarding fish habitat preference, it was also found that fishers have adequate knowledge with respect to fish movement/migration between habitats. According to the information I received from fishers, some fish are residents, for example, *taki and puti* while many others are temporary visitors in the beel area when it is connected to a larger water body such as a river. Examples of temporary visitors are big carps, for example, *rui and katol* and some catfish like *ayre and boal*. Many fish have specific needs for their breeding. Fish like *boal* need wide canals and highly turbid water with adequate water current for breeding. Big carp fish (locally called *rui jatio mach*) travel long distances for breeding. They lay eggs near to the hill streams which are far way from the places they inhabit. This is why local fishers never see the carp eggs, only juveniles. Hatchlings have the local names of *Pona*. According to fishers, downstream areas are important for growth and development of carp juveniles. In such areas, water can spread horizontally and allow *pona* fish to enter areas enriched with food. Down stream areas are locally called *vhati.* When *Beels* are connected to rivers they serve as good feeding/nursery grounds for many riverine species of carp and larger catfish. The river is the shelter for almost all fish, but growth happens in shallow areas like a beel. In this respect, both types of habitats are required for ensuring good fish production.

Fishers reported that habitats are stratified for particular fish. Mud-loving fish are *taki, baim, tengra* or *meni*. Fish like *gutum* (a loach) can survive in mud with low moisture content. They can survive there even for months with no water in the beel basins. Channids and loaches can survive in the abandoned crab holes when beels are completely dry. Fish such as shing and *koi* prefer shallow areas with aquatic vegetation. Their main foods are insects and snails that grow in such habitats. Good fish habitats are partly weed covered and partly clean.

Fishers were found to be very much informed about plants responsible for fish habitat. Fishers reported that the presence of aquatic vegetation is very important for the survival and growth of fish. Very often fishers reported that on the bodies of aquatic plants, a jelly-type matter is found likely a flagellate colony) that serves as good food for many fish. Many plants also serve as direct food or shelter for fish. *Kalmilata* (*Ipomea* species), once a very common aquatic weed, is very helpful in providing fish with food and shelter but they are almost non-existent in beel areas. In addition, this plant is edible as a vegetable. Idris Mia, a 50 year old local fisher from village *Jeolahati*, stated the importance of vegetation to fish in the following way:

Figure 4. A local fisher displaying aquatic vegetation that provides habitat and food for shrimp

"Vegetations help fish growth. They are the shelter for fish. They are the food for fish. Many plants like tetula jungles, sechi jungles (combination of a number of plants) are major spawning place for shrimps. These plants are nonexistent in natural habitat. So, big shrimps are disappearing from beel area".

The above statement made by Idris Mia outlines briefly the importance of plants in fish habitat.

In many cases the information with respect to the use of plants by fish as habitat components was unclear because fishers sometimes referred to a small plant community composed of more than one species as a single habitat for particular fish. As a result it was not possible to correctly identify the role of a particular plant. However, a list is prepared explaining the role of aquatic vegetation that supports fish in different stages (Table 7). In addition to the knowledge about fish habitat component, and their uses, the study identifies that fisheries possess a good knowledge about the trophic structure fish community.

Table 7. Brief list of plants and their uses in the life stages of fish

Local name of aquatic vegetation	Scientific name	Location/ vegetation types	How they support fish	Name of fish
Sechi Jungle	Many vegetation forming cluster	Bank area	Spawning	Shrimp
Tetula jungle	,,	Mid basin	Spawning	Brood of various fish
Shaoli/Sheola	*Ceratopphylum demersum*	Mid basin	Protection for Freshwater spawns and juveniles	Numerous species
Sheoli	*Myriophylum tetrandrum*	Floating	Leaf used as food	Numerous
Kolmi	*Ipomea aquatica*	Trailer on mud or floating	Shelter for fish as fishing can not take place where it grows	Numerous species
Helancha	*Enhydra fluctuans*	Bank area	Forage area of insectivore fish	Taki (*Channa* spp.)
Panchuli	*Nymphoides indicum*	Floating	Leaf used as hiding place for carnivores	Mainly kaikla (a gar fish)
Poddo	*Nelumbo nucifera*	Rooted herbs with floating leaf	Stems hold flagellates (algae) support food for carp fish. Many fish are seen to rub their body with stems when fish are infested by parasites	Mostly carp, but carnivores like snake heads also take shelter beneath the leaf when searching prey.
Shola	*Aechynomene aspera and A. indica*	Along the beels	Egg laying and soft roots on stem used as food of fish	Mostly small shrimps
Pani fal	*Trapa bispinosa*	Mid to bank area	Hiding place as well as food source of fish	Many fish
Topa pana	*Pistila stratiotes*	Floating	Root	Used as food for carp and minnows
Rashnajhaji	*Ottelia alismoides*	Mid basin and emergent	Cover for fish like perch	*Bheda* fish (*Nandus nandus*)
Dal	*Lemna sp.*	Floating	Form thick scum and hide for fish	Numerous
Pat sheola	*Valisnaria spiralis*	Mid zones	Roots are hiding place and food for fish	Numerous, but the preferred zone for *Bheda* fish
Dhap	*Eichhornia crisipes*	Floating	Cover for fish and root and leaf used as food	Mostly of carp as food but hide of all fish. Keeps water cool during hot season
Kochuripana	*Monochoria hastata*	Bank area	Hiding place of fish and flagellates on its stem are food for fish	Mostly carnivore but small fish are also seen to use as habitats

(*Source: Based on the information given by 10 community fishers in a group*)

Like plants, certain fish also contribute in managing fish habitat. During the study fishers described how a healthy fish habitat could be maintained in the presence of *rakhkhushe* *maach* (carnivorous fish). They mentioned that small fish aid the growth of the carnivores by being their food. So the production of large fish such as *Boal* (called freshwater shark in english) is largely maintained by small fish production. In addition, small and medium-sized fish help the growth of *Boal,* it means that low-valued small fish are converted into high priced ones; therefore,. presence of carnivores is economically and environmentally beneficial in natural habitats; it maintains balance pertaining to trophic level. It was reported that a 10-hectare beel needs at least 10 large *Boal* (*Wallgo attu*) couples to maintain good catch. The anecdotal information indicates that fishers, at present, catch mostly small fish in the beel, instead of a proportionate catch of large fish. The presence of more small fish might be related to the absence of the carnivores.

Connectivity of beels with larger waters is very important. Big fish prefer deep canals for moving into shallow areas from rivers during the spawning period. If canals fail to give good passage for large fish, then they do not enter there and spawning is hampered.

According to fishers' knowledge, there is correlation between fish size and the size of the waterbody. Fishers informed me during interviews that past habitats were bigger to support big fish. One fisher described the relation with fish size and habitat, when telling a story from his boyhood as:

> *He used hook to catch fish like Boal using frog-bait. He, at least, catches one big fish at each day of operation. One day came alone for fishing at night time. His father joined him later. He was operating hook as of other days. Suddenly felt if pulling his hook by something. He starts releasing the threads from his wheel. Faster at the beginning and slower afterwards. The fish is hooked for sure. It was moving around. And pulling the thread hard. At some point there was no thread left in the wheel. Getting no other option, the fisher started walking through the bank following the direction of the movement of the fish. It spent about 2 hours. The fish became tired but kept moving. In the mean time the fisher's father arrived. The fisher informed him about the probable catch. At the beginning the fisher could not make his father to believe that could be a fish*

rather he was guessing it might be a dolphin. Finally the fish jumped on the other bank and it was clear to see that is a fish. After few moments the fish start to float on water keeping the belly up. Watching the fish is tired, the fisher rewind the thread and bring the fish nearer to the bank. The fisher hand over the fishing wheel to his father and jumped into the water to catch it but he became frightened to approach when he saw the mouth opening was fairly big and was enough to grab the fisher's head. But when he was quite sure that the fish is about to die then he approached and caught the fish at its neck and pull out to the bank. It was really a huge Boal (English name: Freshwater shark) *of about 3 meter long. They bring the fish at home when it is almost midnight. They awaken all the family members from bed. Everybody become so happy to see such a large fish. One from the family members comments the events in the following way... "Hey!!! The Boal would grab you. Instead, you grabbed it. So funny!!!".*

The storyteller finished the story by taking a long breath and concluding that "the canal is non-existent, so such fish will never show up".

4.3 Fishers knowledge: hydrology/water cycles

The hydrological cycle is also important for fish movement among habitats. Various terms are used locally to denote water movement. water receding is locally called "*Pani Mela kora*", and water arrival is called *bonna or baan*. Water currents influence in- and outward movement of fish in the beel. In general it is believed that fish production increases with high water level, but many old fishers disagree with this idea; they believe that a moderate flooding with steady water level is good for natural fish production.

Fishers are aware of the water availability and its impact on water quality. Fishers pointed out during the interview that less water facilitates pollution and interferes with other requirements of fish habitats. They claim that in the past, there was enough vegetation in the aquatic habitat. The vegetation has disappeared as the water holding periods of the beel have become shorter. The loss of aquatic vegetation is also related to conversion of the beel bed into agricultural lands. The shorter duration of water stay in the beel is also a big threat to fish growth. If beels would hold water for a longer period then there would be more time to grow larger fish and fishers would benefit. Fish catch in floodplains and other waterbodies are determined by water levels as well as movement directions. Floodwater starts receding following the departure of monsoon rains (normally in December). Following recession, fish also start to migrate with the current towards downstream rivers. Fishers reported that a substantial production (more than 20%) of fish is caught during the water recession period. Large fish like carp or *Boal* are caught during this time.

Fishers consider late flooding as a catastrophe for natural fish production. *Puti, mola* (small minnows*), gura icha* (small shrimp) are now the main fish in the catch, and they are the early breeders (May-June-July). If it is a late rain or flood though, successful spawning of the above fish is not possible resulting in low production. Water scarcity reduces fish habitats, and has a severely negative impact on fisheries; it increases fishing pressure as well as facilitating destructive fishing like dewatering. Moreover, in such conditions, as fish habitat holds less water, water heats and kills many fish during the harsh summer months. This was the case in 2004 when fishers reported a large scale death, especially to fish like snake heads, occurring due to low water level. Water quality deteriorates when water depth is less, this stimulating infectious disease, like ulcerative disease, and fish production falls. Late flooding, along with lower water level, also disconnects beels from the attached waterbody. The fishers can attest to the fact that connectivity of a beel with a river is vital for fish production. It helps replenishment of the stocks and contributes to high quality seasonal fishing. It helps improve the overall habitat quality of the beel.

4.4 Fishers knowledge: fishing practices and fish declines

The information gathered during the study reveals that fishers, farmers, and the community members are concerned about the reduced fish production from natural waters. They firmly believe that most of the fish habitats are overexploited and the number of fishers has increased in comparison to the past. Simultaneously, with the increased number of fishers, fishing techniques also have changed. The changes in fishing methods is perhaps connected to the gradual changes in the size of the fish they catch. In the past, the fishers used traditional gears such as *khara jal* (Lift net), *khepla jal* (cast net), *ghuni, chaii* (traps), and *sip* (hand lines). According to fishers, these gears were fisheries friendly and less harmful than the gears have been operating at present. Recently, due to the high population and less opportunity of income from sources such as agricultural laboring, fishing pressure has increased more than ever before. Fishers tend to catch as much as possible, using different types of fine-mesh nets such *Ber jal*, (a seine net, has a mesh size of 2-3 mm) and *current jal* (gill nests),which mesh size varies between 1-4 depending on the size of the fish the nets targeted. According to fishers, these small mesh nets are harmful to fisheries. Fishers rank *Ber jal* ((Figure 5) as the most destructive of all gear, including *current jal* (gill nets). It is so detrimental that it does not allow even small fries to escape from its range. In this regard, fishers are suspicious about the effectiveness of the government policy of blaming the gill-nets. Their observation reveals that *current jal*, a gillnet, is not as destructive as seine nets.

Figure 5. View of operation of seine net, a bag-shaped surrounding net which can be pulled onto a boat or ashore

A *current jal* at least allows a fish to grow to a certain size before it gets caught. This view was supported by a large group of old fishers (55%), but rest also tend to agree with the notion that much damage to the brood and spawns are due to *current jal.* They believe that *ber jal* is very harmful especially for juveniles. *Ber jal* also destroys aquatic vegetation that is important for fish growth and survival. Like fishing methods, there is also controversy between fishers and fisheries managers on the issue of fishing pressure and reduced fish production. It was observed that many fisheries managers and fisheries scientists support that fishing pressure is a major problem for fisheries degradation. But fishers' opinion is quite different from scientists and managers. Fishers believe that over the years fish habitats have been reduced greatly. As a result, natural fish production has significantly reduced. A fisher from village Ashapur vehemently urged that fishing pressure is not a problem related to reduced production of fish . He expressed his view in the following statement:

Ami bishshash kori na je jele barse tai mach nai. Mach thakar jaiga nai tai mach kom.

"... *I do not believe that fish catch has declined due to increased number of fishers. Rather I think that fish habitat loss is the main reason for fish catch decline.*"

Fishers believe that a government program devoted to implementing of fishing rules becomes less applicable with respect to regulation of fishing nets in natural waters because there is less fish habitats left for fishing in comparison to the number of fishers. As a result, fishers are bound to fish to maintain their livelihoods and thus violate fishing rules. Like scientists, fisheries managers and policy-makers, the fishers are also aware of the consequences of harmful fishing practices, but, they say that they have no alternative source of income so they are bound to apply fishing methods which may be destructive.

4.5 Fishers knowledge: causes of habitat degradations and its impacts

Over the years habitat degradation, with respect to natural fisheries in Bangladesh, have become an important policy concern, but a true solution has not been achieved yet. In the scientific community, as well as in management levels, there is enough technological knowledge and measures for the problems with respect to degradation. However, during the study fishers were found to be convergent about reasons for the degradation of fish habitats and its impact on fish production, livelihoods and biodiversity. In this chapter, I have highlighted how fishers see the cause related to habitat degradation and also the impact of degradation in the light of historical fishers' knowledge.

4.5.1 Fishers knowledge: causes of habitat degradation

The study revealed that fishers can identify a number of reasons related to fish habitat degradation. More emphasis was given on socioeconomic and environmental reasons.

i) Socioeconomic causes for habitat destructions

Following the segregated caste systems in the subcontinent, until recently fishing was the profession of a lower caste *Hindu* called sometimes *Jele or Namasudra.* Over the last few decades this situation has been changing fast. Poor people from other religions and castes have become fishers to support their livelihoods. Moreover, with the increased population and reduced income, part-time fishing has also increased to meet the household protein demand. These changes put enormous pressure on the resources and are considered as the major cause of reduced fish production by scientists and stakeholders. In addition to pressure from increased number of gears, fishers blamed various policies (e.g. *Jamohal* management policy) related to fisheries management that lead to low production of natural fish. Historically, natural fisheries have been open access properties. Now, waterbodies are part of revenue management systems in Bangladesh and are managed under as *Jalmohals* systems (revenue oriented management where access right is sold periodically by government to the highest bidders through a leasing system). Though traditional fishers have adequate knowledge with respect to natural fisheries, very often they are not the part of the revenue management systems of fishers. The leasing system brings a new set of people in the harvesting of fish; mostly they are rich and business people who have no ancestral link with fisheries. Lease-holders from other professions have very little understanding about the fisheries resources and often disregard the incentive related to the conservation of fish and fish habitats. Fishers also assert that lease-holders catch as much as possible using destructive fishing techniques and gear. On the other hand, if the fishers were the leaseholders, the scenario could be different. Because it is widely believed by fishers that certain fishing methods (such as dewatering) are destructive to a fisheries, they avoid such fishing as it is the only known livelihood opportunity to them. So they try to ensure every attention is given to conserve the fisheries. A community fisher, Shailen Rajbonshi, age 45 of the village Basuria, described the importance of fish to their livelihood as:

> *"Maach hoitase amader jan. mach paile bhat mukha uthe. Mach na paile amago uposh thakon lage. Income bondo haia jai. Pola pan na khudai more. Amago onno kono pesha nai. Arr amra janio na onno kaj kibhabe korte hai. Tai mach o wetha jatase Amra o wetha jatasi.*

> *"Fish, in turn, is our life. If, we get fish we get food. If we are unable to catch, we starve and our income falls. We do not have other occupation and we really do not know how to switch over to a new occupation. With the disappearance of fish, we are also disappearing."*

In addition to adopting destructive fishing methods such as dewatering and using harmful gears, in many parts of Bangladesh leaseholders are seen to permanently modify the physical features of fish habitats to increase efficiency of the harvest. They sometimes close the waterways, modifying the environment by putting obstacles like temporary fencing up to block the fish movement. In the lease agreement, modification of a waterbody is strictly prohibited under the Fish Policy 1998, but this rule is not enforced, so destruction of fish habitat has become a common phenomenon in Bangladesh. According to fishers, occupation of the fish habitats by the non-fishers may damage the fisheries in a number of ways. Analyzing the fishers' knowledge it was revealed that one reason may function as a triggering agent for the other. Achieving this view, an informal link among various factors related to fish habitat degradations could be established as seen in the figure 6.

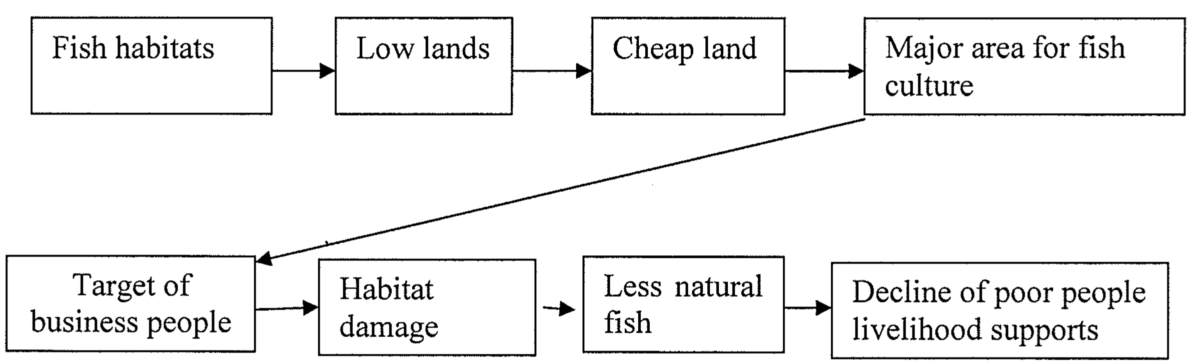

Figure 6. Flow chart of landuse pattern and its connection with habitat degradation

An elaboration of the relation would make clear how the factors are interrelated and impacting natural fisheries negatively. It is widely believed by scientists and managers, as well as fishers that the lowlands serve as important fish habitats. In general, a low-lying area is not good for crop production. Accordingly, such lands are comparatively less demanding for agricultural use than land with good cropping probability that is situated in flood-free areas. Moreover, low-lying areas in beels are good in water retention capacity, helping to developed culture-based fisheries.

It is believed by the fishers and scientists that fish cultivation and depriving fishers are interrelated and compounded by the resource intensiveness of the cultivation techniques. Fish cultivation needs ready cash and skill for achieving good return. These two things are not affordable by the poor fishers. Moreover, rich people adopt modern technology for fish culture and have own manpower for managing the culture area. Though fish culture is profitable in one sense, it makes many fishers jobless because of fish ponds being built in the open water fisheries area and the benefits of low lands go mostly to the rich. As conversion continues, it includes more areas under cultivation, which cause natural fishing areas to be reduced, and resulting in marginalizing more fishers from their traditional rights. According to fishers, when there was less fish farm there was more fish. Fish farming does not help open water fish conservation and production incrementation, not much care is taken for conserving natural fish.

ii) Development interventions and fish habitat degradation

Fishers referred to a number reasons related to developments which cause damage to fish habitat and fisheries. First, there is agricultural conversion. About 90% of the beel basin has been converted into crop land, greatly reducing fish habitat. Second, nutrient-rich topsoil is harvested from beel beds and used for brick manufacturing. Such an area then becomes infertile, useful neither for fish production nor agriculture. Third, there is damage from pesticides and fertilizers.

Farming has a negative impact on fisheries, as it requires the use of much pesticides and chemical fertilizers to increase agricultural yield. About 250 kinds of pesticides are used in Bangladesh. Annually between 4000 to 5000 tons of pesticides are used in the country as a whole, and as much as 25% of this may end up in water bodies. Pesticides at high concentrations are known to reduce the survival, growth and reproduction of fish (Konar 1975; McKim et al. 1965) and produce many visible effects on fish (Johnson 1968).

Even at sub-lethal dosages, aquatic species that are part of the food web may be harmed. There is also a high dependence of chemical fertilizers in Bangladesh. According to BARC, there are approximately 12 million hectares (ha) of lands under cultivation in Bangladesh. The amount of chemical fertilizer use was 1.28 millions tons (1995/96), at a rate of 100 kg/ha (Parvin and Islam 2002). These chemicals contaminate soil and water, enter into the food web, and cause bioaccumulation of toxic substances in aquatic animals. In the study area, farmers argued that there has been a drastic reduction in the use of organic fertilizers such as cow dung which, in general, are considered as environmentally friendly. One fisher from the village of *Mudipara* commented that poisons (referring to pesticides) are always harmful for fish and their habitats.

Fourth, damage to fish habitats also comes from unplanned rural infrastructure development such as roads. This has detrimental effects on fish habitats when it blocks migration routes. Similarly, most of the big and small industries also discharge pollutants directly into the nearest waterbodies and rivers. Fishers mentioned that though the study area has no direct link to flood control embankments, country-wide there are a number of flood protection schemes impacting negatively to the resource systems. Human interventions, especially sluice gates, prohibit easy flow of water and impact natural fisheries production negatively. It serves as a barricade to natural fish, as well as for juvenile fish when moving towards beel and flooded lands. Fishers are concerned about the construction of sluice gates and its mode of operation. They agreed on putting water control structures as a flood protection measure, but pointed out that that the operation of the sluice gates should be well coordinated to include consideration of fish movement.

iii) Environmental reasons of habitat degradation

Fishers believe that, there are environmental causes related to habitat degradation. The big factor regarding natural degradation is the deposition of silt carried over by the floodwaters in the beel beds. They mentioned that the off-take area of the river *banshi* (most important river for fish generation in the study area) is almost blocked due to siltation, and as a result the flow of water is now reduced. Reduced water flow further increases silt deposition in the adjacent beels and river scours. A river scour is locally called *Doab*. According to local fishers, *Doab* is important for dry season refuge for fish, but high siltation process is damaging this area. Silt deposition in the migratory route deters the inflow of juvenile fish or can permanently block the migration route if the process is so intense and no steps are taken to reopen it.

4.5.2 Fishers knowledge: Impact of habitat degradations

While changes have been occurring in fisheries habitats, fishers perceive impact with respect to biophysical and socioeconomic aspects. They encounter the changes with respect to the overall biotic community of the beel comprised fish production. These changes also affect negatively on the fish diversity, profession changes, and livelihood income and nutrition level. Detailed impact study related to socioeconomic and biological aspects of the fisheries was not possible during this study. However, a brief account with respect to perceived impact is outlined in the following subsections:

i) Habitat degradation and its impact on overall biotic community

Traditionally, the study area was the home of many other aquatic animals besides fish. Many aquatic organisms other than fish have contributed greatly to local people by providing income and food. While habitat changes are evident, fishers observed a number of changes both in the animal and plant communities of the study area. Among many other causes of habitat degradation, the cause related to agricultural development is intense. Fishers mentioned that while beel beds are converted into agricultural lands, much of the perennial vegetation, such as water lilies has disappeared. The vegetation disappearance facilitates growing of a new set of seasonal vegetation such as water hyacinth *Echhornias*, *reeds Fragmites sp* (see figure 7). Local changes in the vegetation bring changes among animal diversity in a particular fashion. Fishers noticed a big change in the bird fauna in the beel area.

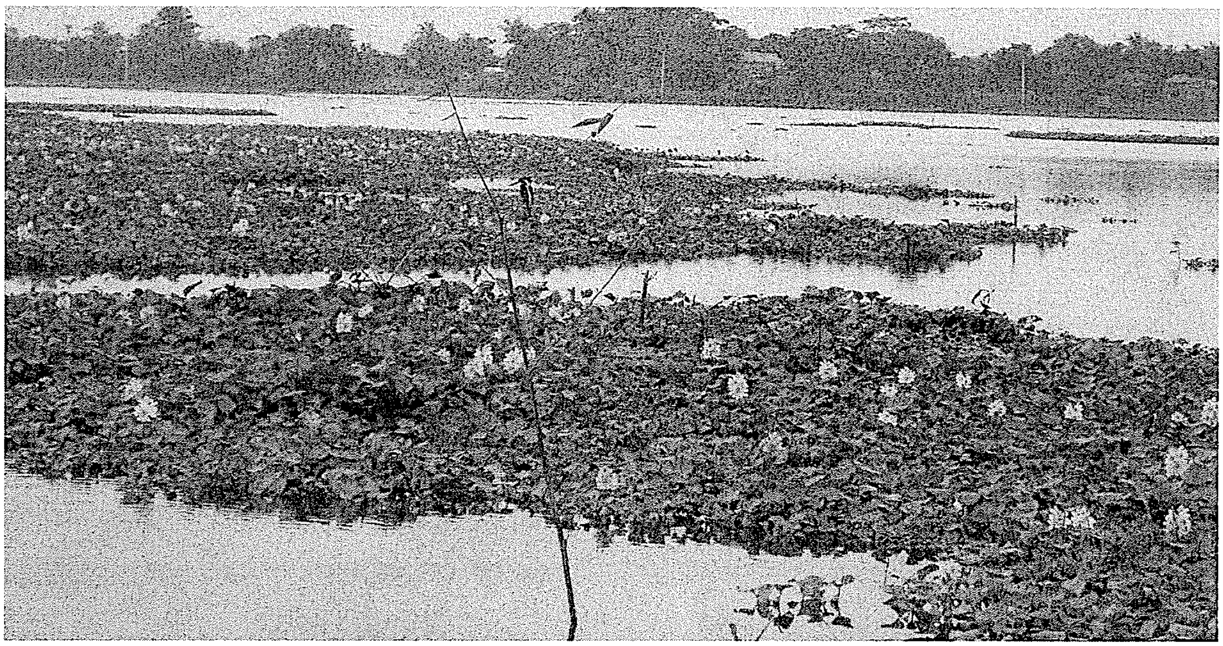

Figure 7. A cluster of water hyacinth clogging up a beel

In the past, they would often see the moorhen (locally called *Dahuk*), a resident water-bird sitting on the mat/scum that is produced by thick vegetation. The vegetation also helped nesting and spawning of many aquatic birds such as cormorants. With the disappearance of perennial vegetation, cormorants and moorhens have disappeared. At the present, a vast area of the beel is now vegetation free during the wet season (Figure 7). The vegetation free area has several impacts on the fish population. It helps the growth of some surface feeding fish (*chela, kaski, mola, puti*) while it brings more pressure to fishing by the use of destructive gear such as seine nets. Along with the changes in the avifauna, fishers mentioned that they remember the presence of a number of reptiles such as water snakes, Bengal monitor. This species have completely disappeared from the study area. Reptiles are never consumed by most of the local people, but they are harvested for food by a local tribe called *Garo* who have been living in the northern-central highlands of Bangladesh.

ii) **Habitat degradation and its impact on livelihoods**

According to fishers, about half of the beel bed is lost due conversion of *beel* area into agricultural land. In addition, due to siltation there has been a drastic change in the depth of the beel. Fishers in the focus group discussions mentioned that during 1960s, the depth of the beel was about 10-12 meters at the time of peak flooding (August-September). Now it reaches only 0-3 m. Fishers believe that reduced depths and area are the major causes of fish decline as they do not support diversified habitats for fish broods as well as dry season refuge. Table 8 shows the summary result of resource mapping workshop which highlighted historical degradation and socio-economic adjustment in the beel area. Fishers gave an estimation of how increased rice production has impacted on the fish production. They also linked the fish production to the population changes and development of subsequent growth of alternative source of proteins (Table 8).

Table 8. Fish habitat changes and socioeconomic adjustment in the beel area

Year	1960	1980	2005
Depths changes (m)	15	10	3-4
Estimated total perennial water area (ha)	100	60	20
Population (per square mile)	200	700	1500
Rice production (ton)	4000	6000	12000
Fish catch (in ton)	20	8	5
Domestic source of protein (Poultry etc) (ton)	0.5	2	10

(Source: *Resource mapping workshop*)

The development of alternative sources of protein partly balances the shortfall of the fish production from natural sources, once a prime source of animal proteins to Bangladeshi people. Though various alternative processes are gaining more attention as sources of proteins, local people still prefer the recovery of natural fish.

Traditional fishers showed a number of concerns with respect to the changes in their nutritional levels and household incomes. Traditionally, community fishers did not possess agricultural lands. So, conversion of the fish habitats into other forms (e.g., agricultural lands) has greatly reduced the opportunity for fishing. According to fishers, the fish are even unavailable for their consumption. Facing such scarcity, many community fishers have already had to change their traditional professions. In general, fishers are poor and cultured fish available in the market are often so costly that are beyond their purchasing capacity, So, they are suffering from malnutrition. Due to habitat degradation good quality fish was almost non-existent in the study area. Absence of good quality fish catch is one of the biggest reasons for the loss of income from fishing. No reliable official records regarding changes in the fish catch were available during the study. Information available from the local fishers could greatly fill the gap in catch statistics. Depending on the present study, an outline related to historical changes/shifting of fish stocks in the beel is given in the Table 9.

Table 9. Historical trends of fish production in the beel

Local name (major group)	English name	% (30 years back)	% (at Present)
Rui jatio mach	Carp fish	40	1
Boal/shing/magur	Large catfish	10	1
Koi/bheda	Perch	2	0
Tengra	Small cat fish	4	2
Taki/shol/gozar	Murrel	2	10
Baim	Freshwater eel	2	1
Puti	Minnows	15	50
Gura mach	Miscellaneous	15	20
Chingri	Small shrimps	10	15
		100	100

(Source: Based on resource mapping workshop. Number of participants 7)

Fishers claimed that the past catch was mainly composed of good quality fish like *koi, magur, shing, and rui* type of fish, but recent catch is composed of small indigenous fish locally called *gura maach*. The major contributing group in *gura maach* is a group of minnows comprising 50% of the catch. The catch of minnows is followed by some other small miscellaneous fish such as loaches *(gutum*), small catfish (*tengra*) and small shrimp (*gura icha*).

CHAPTER 5: ROLE OF LOCAL KNOWLEDGE IN CONSERVATION AND RESTORATION

The study discovered that living historically nearer to the beels and having fishing, either as a livelihood income or subsistence, local fishers hold multi-dimensional knowledge of fish habitat. It was observed that in the wake of continual degradation of open water fish production, local fishers and farmers are concerned ab out habitat degradation threats posed. They believe that, they will lose their major source of livelihood incomes as well as a cheap source of proteins for themselves and for their neighbours if habitat can not be conserved or restored. In this connection, they focus on the conservation and restoration of various habitats by adopting locally available techniques and processes where their knowledge can play a significant role. They also reinforce various measures of habitat restoration and conservation that link to developmental activities of the government.

This section of the thesis focuses on the views held by the fishers and local peoples, as well as fisheries managers and scientists, with respect to habitat restoration and the conservation process. I will hereby focus on the strategies and approaches of conservation and restoration as proposed by both local peoples and fisheries scientists and managers to conserve fish and fish habitats. Also included is a list of projects where fishers have started to contribute through their knowledge.

5.0 Local level approaches for habitat restoration and conservation

A number of techniques and processes for local level restoration and conservation were discussed, especially during focus group discussion meetings composed of fishers, local stakeholders, as well as personal interviews with fisheries managers and scientists. Both fishers and fisheries managers and scientists were found to be aware of useful techniques and approaches of local level conservations. The views held by local stakeholders, fishers and farmers, as well as fisheries managers with respect to various methods applicable to conservation of fish habitats, are highlighted in the below subsections.

5.1 Local level approaches for habitat restoration

Local fishers mentioned several locally available techniques with respect to restoration of degraded fish habitat. In this subsection of the thesis, I include several approaches of how fish habitats can benefit through adopting local approaches.

5.1.1 Restoration by agricultural cropping patterns

Historically, paddy farming practices have been a direct relation to fish habitat conservation. Before the introduction of High Yielding Varieties (HYV) most of the local varieties of paddy helped fish habitat conservation in openwater fisheries. Fifteen to twenty years earlier, the paddy had been cultivated in the wetland area of Bangladesh and was mostly composed of deep-water rice. Recently, there is a considerable expansion of *boro* cultivation (HYV varieties) which has replaced the deep water rice. Fishers believe that deep water rice (Figure 8) is responsible for ensuring habitats of many highly desired and formerly most common species of fish like *koi* and *shing*. It is firmly believed by the farmers and fishers that at least one species of perch fish *Koi* (Climbing perch) decline is linked to changes in cropping patterns. Importantly, *boro* rice is considered a water hungry crop. In this practice, surface water abstraction is increased, causing habitat damage. It is important to note here that farmers prefer the use of surface water because it is less costly and good for soil. Following the negative consequences of *boro* cultivation, fishers propose alternative uses of the *boro* rice area to restore previous types of cropping system. Cultivation of onion and garlic in dry season and deep water paddy in wet season and might be more profitable than *boro* cultivation and also helpful for fish habitat conservation. These types of crops need less water; thereby the risk of habitat damage

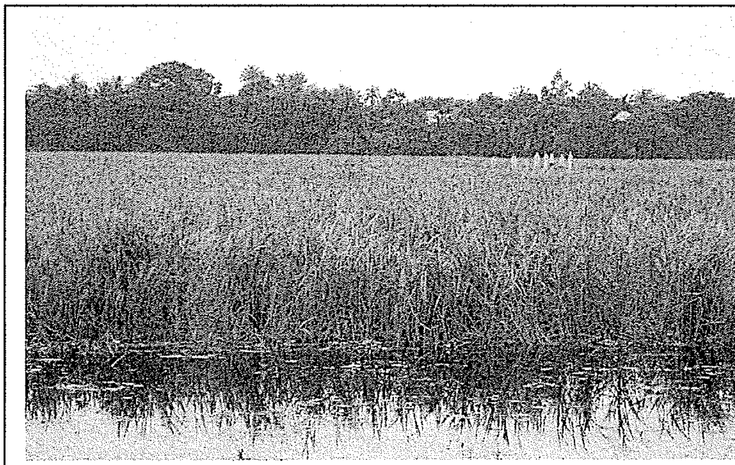

Figure 8. A view of deep water paddy

by water abstraction in dry months could be avoided. This type of cropping system has other benefits as well. Such crops are harvested during peak poverty-prone months (April-May) in Bangladesh. These are also less input crops. Considering the above situation many fishers expect that the deepwater rice could be retained for conserving fish habitats. Deep-water rice also prohibits seine operation which is the most destructive fishing in open water.

5.1.2 Restoration by the maintenance of habitat diversity

According to fishers, fish production takes place in combination, and by the exploitation, of different fish habitats in turn, which are needed for spawning, nursing, and feeding and growth of fish. The fishers propose that both shallow and deep, as well as small and large, habitats are required for the healthy production of fish. Also, connectivity among habitats is vital for fish movements as it enhances the diversity of fish in a beel. In general, a beel connected to the larger waterbody such as river, exhibits higher fish diversity in comparison to a beel with no connection. Fishers are aware of the resource systems of many water bodies and point out that though rivers are the shelter for all fish, production of fish occurs in the shallow area like a beel. In local terms a river is a *vander* (storage) of fish. It saves fish from being harvest during dry months (February-March-April), and allows them to disperse to other places that are important for their life cycle. In the case of considering programs with respect to restoration, habitat diversity should be maintained. Fishers mentioned that a number of river scours in the river *Banshi* serve as the main source of regeneration for the fisheries in the study area. I was informed by the local fishers that as the fishing area gets highly reduced during the dry months (April-May), river scours encounter more fishing pressure. Improved management, such as the protecting river scours to ensure restoration and conservation of fisheries was suggested.

5.1.3 Restoration by maintenance of connectivity

Fishers, fisheries managers and scientists interviewed indicate various types of eco-friendly measures with respect to restoration of degraded fish habitats. These include removal of obstacles in migratory routes (e.g. silt removal from dead canals and removal of embankment), as well as keeping provision for adequate bridges/culverts in the migratory routes which can ensure connectivity between habitats. It was reported that due to the changes in the natural environment, as a result of human-made interventions like dykes along the water courses, the passages are either blocked or converted into narrow passages that aid in the easy catch of fish. According to fishers, *ma maach* (brood fish) are weaker and get caught easily during spawning migration. Removal of obstacles like weirs, fish fencing, the opening of damaged sluice gates, and excavation of silted canals could be considered vital steps for making the fish habitats functional. In addition, more bridges/culverts are required when constructing roads across the beels (Figure 9a).

a) Bridges for fish movement

b) View of excavation of a silted canal

Figure 9. Fisheries-friendly measures for restoration of fish habitats (*source: CNRS, Bangladesh*)

The local fishers informed me that most of the migratory routes, especially canals, are now degraded as a result of silt deposition. A silted canal does not enhance the fish migration instead it creates ways for a good fish catch area. Fishers suggest excavating in such way that it helps the fish migration (Figure 9b). Along with excavation, enforcing regulations with respect to brood fish conservation is needed. They suggest forming a surveillance post to guard the key fish migration spots during the peak spawning season (May-June). In this respect, fishers informed me that the government intervention would remain rather inadequate and they referred to other alternative processes. Among the alternatives, they supported digging the beel beds and helping to conserve water during harsh summer months (March-May). This water reservoir could be saved and used as a fish sanctuary. The traditional *kata* (brush piles for saving fish) system could tremendously support the fish habitats if it is adequately adapted to the conservation process.

5.1.4 Restoration by the use of sanctuaries- *kata/kua* sanctuaries

During the study it was found that a number of habitat restoration and conservation programs are undertaken by the community at beel levels. Community fishers have established fish sanctuaries, excavated migratory routes to develop connectivity, and established small fish passes or fish-friendly structures. The most commonly used methods for conserving fish habitats as well as fish diversity is still the traditional *Kata* sanctuaries. Because of this, a short case study that covered three *kata* areas was done. The information included here was also supported by as recent study made on kata fisheries in Bangladesh (Ahmed and Ahmed 2002). The investigation highlights how these traditional techniques of fishing served as sanctuaries. It also includes some management and related conservation aspects of their technique.

A *Kata* sanctuary is a version of traditional brush pile fishing (one of the traditional fishing devices used in almost all inland waters). In kata systems tree trunks or limbs lying partially submerged provide cover and spawning areas for many fish species (Welcomme 2002). species. They are particularly rich trophically because of the abundance of epiphytic organisms, boring insects and mollusks on the submerged surfaces of the wood and the root systems, and because of the enriched bottom mud caused by decay of the woody material.
The differences between traditional fishing kata and sanctuary kata are in how they are used in fisheries, for example, conservation or fishing devices. The *Kata* system is highly favorable when it is used for fish conservation as it helps in maintaining habitat diversity by restoring various components required. The Flood Fish Habitat Study of EGIS (1997) identified that habitat use by fish varied greatly. In this context, protection of habitats and sub-habitats are important. It is interesting to note that in the *kata* system, both macro and micro habitats are restored to support biodiversity in a habitat (Ahmed and Ahmed 2002).

Various investigations indicate that *kata* serves as a good fish aggregation place with high species diversity. Fish settle there for food, some for shelter, and some for spawning purposes. As a result, *kata* can be considered important for habitat diversity. Considering the habitat supporting nature of *kata*, very recently this indigenous fishing technique has been treated as the pathway of today's idea of fish sanctuaries or protected areas.

Kata sanctuary is not recommended in narrow canals as it may block the local navigation. However, in the wet season it may be an effective mechanism to protect the migration route. When *kata* is used for a restoration of fish habitat, it possesses several features: it maintains a defined zone, along with a neutral zone, surrounding the fishing area that covers 15-20 feet encircling the core zone. To distinguish areas surrounding the *kata*, the core zone of *kata* is marked by several red flags. A signboard is also placed near the *kata* to state the objective of the *kata* construction. In general, *kata* is established in the deepest portion of the waterbody so that shifting is not required when the water level goes down in the dry months.

A number of living and non-living materials are used to construct a *kata/kua*. Table 10 shows a brief list of *kata* materials.

Table 10. List of major kata materials

Serial number	Local Names of materials	English/ Scientific names	Type of materials	Uses
1	*Banshser nola/konchi*	Bamboo stick	Non-living	Framing and fixing the kata zone. Protection from illegal fishing
2.	*Gaser dal*	Tree branches (Tamarind, Mango, *Hijol Baarringtonia sp*., Korach *Pongamia tinnate etc.*)	,,	Shelter for fish. Fishers believe that the bark of branches and the latex of such trees were also used as food for fish.
3.	*Gaser gora*	Tree roots (for example Bamboo, mango)	,,	Shelter for small fish.
4.	Water hyacinth	*Ichhornia cricipes*	Living	Shed of the *kata*. Roots used as food for carps and minnows, protection from water birds.
5.	*Kolmi lota*	*Ipomea sp.*	,,	Shelter and food
6.	*Saholi*	*Ceratopphylum demersum*	,,	Fresh laid spawn and young fish protection and food of shrimp
7.	*Helancha*	*Enhydra fluctuans*	,,	Forage area of insectivores *Taki* (*Channa* spp.)
8.	*Rashnajhaji*	*Ottelia alismoides*	,,	Good habitat for carnivore species

(Source: *Survey data on kata materials*)

Among non-living matters, branches and roots of local trees are commonly used to form the bottom and middle part of a *kata*. A number of living aquatic vegetations are used as shedding materials in a *kata*. Common shedding material is floating vegetations such as water hyacinth. A number of emergent vegetation like reed, are also used to form the top and middle part of a *kata*. Branches of trees like *hijol, tetul*, and mango used in a kata. Periphytones are seen to form on the branches put in the *kata* heap what is locally called *sheola*. According to fishers, fish and shrimp gather mostly for the availability of periphytons as their main food. *Kata* is constructed to protect fishing, but it is likely that the predatory effect from larger carnivores is prevailing. Fishers propose eliminating predatory fish if their presence is assumed to be increasing. Less water in the dry months level makes the fish extremely vulnerable to pollution and increases the risk of disease infestations. Fishers informed me that during this time, a thick cover of kata materials, such as water hyacinth, creates anoxic conditions and contributes to fish death.

The species composition in a sanctuary resembles the available species in the waterbody. However, a remarkable change with respect to overall species biomass occurs after the construction of a *kata*. In general, it is observed that the production of silurids (*boal, shing* etc) and bagrid catfish (tengra and ayre), increase after *kata* construction. According to fishers, predominance of these species is attributed to the changes of such habitat features as availability of food and shelter. A list is prepared (Table 11) from the investigation made on catch data of the study area.

Table 11: List of fish that prefer *kata* sanctuary

Species found	Scientific names/group names	Percentage (%)
Tengra	*Mystus vittatus*	14
Ayre	*Mystus aor*	6
Boal	*Wallago attu*	12
Shol/Taki/gozar	*Channa species*	15
Spiny eels	*Mastacembelus spp.*	5
Puti	*Puntius spp.*	15
Perch	*Chanda Spp*	8
Other species (about 30 species)	-	25
Total		100%

(*Source: Based on the 3 special surveys on kata sanctuaries in the study area*)

As a new process of fisheries conservation--by kata construction--information is not yet available to quantify how much area is required to conserve and support fish population and to make the process sustainable. In general, fishers propose to conserve part of the fishing area because it is not possible for them to abandon fishing in the entire waterbody. Many fisheries mangers and scientists believe that 30% of the dry season area should be conserved. But this calculation is based on assumption and is not supported by any reliable documents. However, a study by Ahmed and Ahmed (2002) revealed that at least a 0.20 ha water area would be required to support a 100 ha waterbody.

Though *kata* serves as an effective mean of conservation, many inherent issues have evolved concerning the sustainability of the process. Effective management practices of the resource are needed to ensure successful conservation. Fishers and scientists are aware that *kata* operation for fish conservation has been continuing mostly in project waterbodies implying that this practice only works under support of project money while there have been very few examples of publicly maintained *kata.*

Erection of *kata* sometimes creates conflict in terms of fishing. Fishers generally are not motivated to leave areas un-fished, even if they are interested in seeing more fish reserve in the fishing area. Conservation issues are accepted mostly by the fishers, whereas private *kata* owners are still interested in seeing *kata* as a fishing device rather than mode of conservation. So far there is no policy at the government level for sustainability of the *kata* sanctuary and the management process is still not clear to parties involved (fishers, land owners, managers and scientists involved in fisheries management).

5.2 Social perspectives in conservation of fish habitats

Local fishers and stakeholders surrounding the beels described several conservation approaches that link to social settings and historical involvement, as well as to the ethical values of people with fishing. These approaches refer to collective action, exploring ethical values and expect changes in contemporary management such as leasing of waterbody.

5.2.1 Local involvement in conservation

From discussions with local fishers, farmers and fisheries managers, it was evident that for formulating management with respect to conservation and restoration, there is a need for local participation from different levels of the social hierarchy. It was found that fishers were aware of their financial incapability to initiate any conservation measure beneficial to the fisheries. In the same way, they also raise concerns about the lack of collective action for the development of the resource, both locally and regionally. Fishers mentioned that very often fishers and stakeholders are divided in meeting the conservation needs, like maintaining closed season, and the banning of harmful fishing such as dewatering. They pointed out that the village leaders have adequate influences in guiding local fishers, but they hardly come forward to prohibit destructive fishing that affects fish habitat. Like fishers, fisheries managers also believed that village leaders can play a key role in the habitat conservation/restoration process. In this respect, limited information was collected that is hardly worth mentioning on a collective local action including local leaders. However, fishers also mentioned that intervention from the government side is urgent, when considering habitat restoration measure as a collective action to fisheries management. But they agreed that if the local people do not willingly come forward to conserve/restore the resource, then it is hardly possible for government to achieve the goals. Government officials in the Fisheries Department were also found be aware of the need of participation. Many officials agreed in their limited capacity, with respect to manpower and funding, to be involved in various collective programs and informed me that fishers' participation is important especially in managing fish sanctuary and the implementation of the Fish Act. Unfortunately, a broadly based government policy has yet to be formulated that acknowledges the needs of public participation in fisheries management and planning.

5.2.2 Leasing and conservation

The present study and information available in various records reveal that leasing has been negatively impacting natural fish conservation/restoration. Very often concerns are raised relating to the leasing of fisheries areas to non-fishers. Fisheries managers and fisheries scientists hold the idea that all will fish once fishing rights are handed over to them by means of lease. However, very often it is argued by the fishers that fishing by the community fishers and fishing by the leaseholders from outside do not have similar impacts on fishing with regards to conservation and management. I interviewed five fishers and three leaseholders to get their stance on fishing. On the basis of the available information from fishers and leaseholders, it was evident that there is a distinction between fishing by community fishers and fishing by non-fishers. Fishers explained their stance on fishing links to their livelihoods, while the leaseholders explained their stance on fishing is as a business enterprise. In Table 12, I have outlined the information received from the local fishers and lease-holders with respect to leasing and conservation of fish.

Table 12. Evaluation of conservation efforts between the lease-owners and fishers

Attributes	Lease holders/private owner	Local/ community fishers
Use of gears	Modern fishing devices like big seine where numerous fishers are seen to operate and massive fishing takes place.	Small-scale fishers do not have modern and effective devices rather they use the traditional gears.
Investment	Able to invest huge amounts money to establish brush piles (a highly effective fishing mechanism, sometimes its purpose is not conservation), and purchasing efficient gear creates huge fishing pressure.	Investment capacity of fishers is limited. As such, establishing big brush piles or hiring a big seine or pumping is not possible for them and fishing is always moderate.
Level of emphasis in fishing incomes	In general, investment is bigger and recovery of the money invested is very important with adequate return. As a result, fishing is always target oriented. In such case, very often fishing turns into intensive as well as destructive.	Involvement of fishers sometimes is not obligatory (subsistence) and in many cases, it for recreation that they invest their self labour; it is no matter to get less fish or give up fishing or continue with fishing. They do not have any hard and fast need to fish. As a result, intensive fishing does not take place.
Destructiveness	High trends in recovery of invested money has pushed to dry-out the area using powerful pump machines or large and effective gear like big seine nets that are dangerous to brood fish.	Most of the community fishers have no such capability to use pumps so risk related to habitat damage is minimal.

(*Source: Based on the view held by five fishers in a group and one local leaseholder*)

In my brief investigation on these issues, it became evident that leasing may affect fisheries in different degrees depending on who owns the lease. In this regard, fishers outlined their views as to how fishing by lease holders/private owners is damaging to a fisheries, as opposed to how fishing by the general fishers is beneficial. To research this answer, I talked to five fishers in a group and one lease holder from non-fishing community. I tried to evaluate the fishers' claim that fishing by them is not harmful, and received some interesting answers with respect to leasing and conservation of fish (Table 12).

5.2.3 Ethics and values in fish conservation

Most societies have developed ethics and values with respect to the management of natural resources. Social values have evolved around people's livelihoods and nature. Many conventions, rituals, and norms evolved over centuries are reflected in various traditional resource management practices. With the application of modern scientific approaches, traditional norms and values have been ignored, and utilitarian approaches have marginalized traditional belief systems (Dr. E. Haque, pers. comm.). The incorporation of traditional social beliefs, norms and practices into modern management systems became a major debate since the beginning of conservation movements in the late 19th century (Jepson and Whittaker, 2002). However, reliance on traditional values and ethics for conservation may be insufficient to achieve sustainability. Giving that a detailed account of environmental values and ethics in the study area has not been possible, my investigation gives a limited idea about their usefulness in conservation and management.

Very often fishing pressure of a certain species is driven by the market demand. As a result, conservation of certain species in a small waterbody like beel has been a challenging task. It was found that social beliefs and customs also play a significant role in determining fishing pressure of a particular species. Many beliefs and customs are helpful for conservation of fish species and fisheries as a whole. Here I will describe briefly how market demands and social beliefs interact with fishing. I discussed conservation issues of two indigenous fish called *shing,* (catfish) and *gozar* (snakehead fish). According to fishers, *shing*, a highly desired fish in Bangladesh, faces a lot of fishing pressure (about 7-8 Canadian Dollars per kg). The fishing pressure related to high demands also related other reasons. Such as *shing* is widely considered as a substitute to medication, as well as a delicious food for patients and kids. As a result, fishers introduce various types of fishing techniques, like de-watering of the entire waterbody, which result in damage habitats for other fish too.

Gozar has very less market demand all over Bangladesh. People generally avoid the fish because of its allergic effect on the human body. More importantly, there are local beliefs, however unproven, that consumption of *gozar* fish is bad for pregnant women because of potential harmful effects to the fetus. The social belief and minimum market demand help the fish to survive. As a result, the fish has less fishing pressure. Fishers are eager to pass such socially-based beliefs to new fishers at time when conservation of certain valuable fish has become very important. Fisheries managers hold different views when thinking of conservation and they refer to ecological restoration/conservation of the threatened species.

As is common in the study area, fishers in many parts of Bangladesh still follow various traditional customs related to fishing. Community fishers from Hindu do not fish during the month of December for 2-3 days (why is it was not sure to them) during their religious festival like *Durga Puja.* But a customary suspension of fishing of 5-7 days was very common in the past. In the past, community fishers also do not fish during the Bengali month of *Baishakh* (May-June) when most of the natural fish carry mature eggs and ready to spawn. Fishers agreed that these customs are still part of many fishing groups. Unfortunately, currently, it the suspension of fishing is hardly followed. Fishers find that such customs have some direct and indirect implication in conserving fish. It helps the fishers to follow limited fishing on one hand, and help them to abide by social rules on the other hand. In the past it was mostly community fishers who had been participating in fishing as their customary right. At the present, fishers are composed of community-fishers as well as from different ethnic backgrounds. As a result, social rules related to fishing are loosely followed. Many of the community fishers hold the idea that there is no benefit from following social rules when other fishers will still be fishing in their absence. Establishing the fishing rights of the community fishers might have a positive impact in the implementation of fish rules that would help fish production increment and habitat restoration even in the absence of rule of law.

5.3 Kinds of knowledge used by fishers for habitat conservation

Traditionally, local fishers have applied various knowledge to managing natural fisheries. The knowledge is seen with respect to conservation of water and maintaining water quality to control diseases in fish. A brief description of the kinds of local knowledge and their applications are given below:

i) **Water quality management in ditches of beels**

In many private beels of Bangladesh, conservation of part of the waterbody in dry season has been important for managing stock of natural fish. In this process, fishing remains prohibited on part of the deeper portion of beel. In the dry months, the protected area holds fairly little water (2-3 feet). Following the low water level, water quality deteriorates. Due to poor water quality, many fish die either by suffocation or infestation of diseases and there is huge loss to the stocks. To prevent fish death, management of water quality is important. The conventional purification methods of water by means of various chemical treatments (for example, liming) is not feasible for environmental reasons as well as cost-ineffectiveness of the treating agents. There are some proven local level alternatives to solve problems related to water quality degradation. Traditionally, fishers have been using local techniques with respect to purification of water in ditches in open beels. In this system, fishers divide the conservation area into sections. Some sections are used for fishing while some remain unfished. The fishing in such sections is done by dewatering. The partial fishing provides a number of benefits. The fishers harvest mostly the big carnivores to reduce consumption of small fish in the ditches. At the time of dewatering, cleaning of the aquatic vegetation is also partially done. The area is then kept exposed to sunlight for a few days and again refilled with the water from the unfished area. This process of refilling dry areas with water from unfished area carries fish to new area and helps reduce the density of fish, which is very helpful to fish survival. Moreover, exposing parts of conserved area to sunlight helps to remove overall toxic loads from the soil and reduces water pollution. This type of fishing also helps fisher by providing part-time income in the lean season.

ii) Thinning of aquatic vegetations for disease control

In Bangladesh, establishment of sanctuaries in closed beels, on order to conserve fish in the dry season, is considered vital to management of fisheries. The basic construction materials of the sanctuary are aquatic vegetation and locally available branches of trees (used as brushes). The brushes and the vegetation stacked in the conservation areas protect fish from being caught as well as their consumption by fish-eating animals. Following low water level, the average area shrinks during dry months. The water pollutes and kills fish in the conservation area due to suffocation, as well as infestation by disease like fish ulcer. As a remedial measure to such problems, fishers apply local techniques like adding more water to the conservation area or helping water movement for aeration, all the while being aware that water movement facilitates aeration in the conservation area. Thus, fishers continue occasional fishing in the conserved and target mostly carnivorous species. Removal of carnivorous species conserves other small fish species.

iii) Re-establishment of aquatic and shore-line vegetation

Chapter 4 (section 4.2) identifies that aquatic vegetation serves as an important habitat component to fish by providing food, shelter for over-wintering, spawning and nursery grounds and places to hide. Fishers believe that there might have been a link between the presence of aquatic vegetation and the survival of a particular type of fish. In this sense, vegetation plays an important role in the life cycles of fish. However, the human interaction with the habitat levels (such as agricultural farming) cause damage to many important vegetations used as habitats components for fish. Very often, complete damage of vegetation is done by uprooting vegetation in the areas that fishable. Reclamation of fish habitats during dry months for agriculture is also done. Fishers in the study area claimed that the recurrent uprooting of aquatic vegetation for agricultural purposes has caused the permanent disappearance of many species of aquatic plants such as the water lily. Reintroduction of the vegetation that has already disappeared from fish habitats could help to maintain habitat components. In addition to fully aquatic vegetation, fishers also claim that depletion of shoreline tree species, especially *Hijol* (*Baarringtonia acutangula)* and *Korach* (*Pongamia* *tinnate)* due to habitat destruction and overexploitation give communities of this area less indigenous fish to harvest than past. Given the importance of such plants, fishers with the help of funds received from projects such as CNRS-managed project Bangladesh (CNRS 2005) have started replanting shoreline trees as well as aquatic vegetation, especially in the *Haor* areas (large natural depressions situated in northeastern part of the country). Fishers believe that at least one species of major carp called *Kalibaush* (*Cirhinnus kalbasu*) uses the exposed underwater roots of these plants to affix their eggs (CNRS 2005).

5.4 Various programs that have begun to partially use fishers' knowledge

Chapter 3 describes how fishers and local stakeholders in the study area hold relevant knowledge with respect to fish habitats and fish behaviors related to migration, other biological characteristics of fish, and interaction of fish with their habitats. Chapter 3 (Section 3.5) also details knowledge of fishers with regards to causes of habitat degradation and the impact of various degradation measures to fisheries. In this subsection, I focus on some contemporary habitat restoration programs where fishers are beginning to contribute through their local and traditional ecological knowledge (Table 13). It is commonly believed that, in Bangladesh, the building of dams, embankments, and regulators have been done without any regard fish migration. Moreover, natural siltation and resulting blockade of water passages have not been considered as factors in natural fisheries degradation.

It is reported that flood control measures have contributed to the loss of more than two and half million hectares of the active floodplain (MPO, 1987). For the first time, "Fish Policy 1998" called for mitigation measures such as fish passes and the development of fish sanctuaries. Very recently, a few projects have kept provision for habitat restoration in their project designs (FFP 2002, WFC 2004 and MACH 2005). In such programs, provisions are also created for public participation so that their knowledge could be used in designing and implementing the program.

Table 13 summarizes the activities of recently completed or ongoing projects in Bangladesh.

Table 13. Major fisheries management projects that have begun to partially use fishers knowledge in Bangladesh

Name of habitat restoration program	Name of project	Responsible organization	Major Activities	Vision
Small fish passes/culverts, bridges and dam removal	Small scale water management project	Local Government Engineering Department Bangladesh (LGED) funded by JICA.	Development of environment friendly aquaculture (Rice-Fish cultivation) and enhancing natural fish migration by eco-friendly structures	Encourages living alongside flood, rather than emphasizing the containment of floods
Fish sanctuary/ excavation of degraded canals; silt removal from migration routes	a)Community - based fisheries management project-2 (CBFM-2) Bangladesh b) CNRS Bangladesh	a) WorldFish Center Bangladesh. Funded by DFID in cooperation of local NGOs and DoF/ b)WorldFish Center	Participatory management and improvement of fisheries including fishing restrictions, fish sanctuaries, habitat restoration and stock enhancement.	Access rights of fishers in open water and helping fish production through community participation.
Fish passes, sanctuary, removal of silt from migration channel	Fourth Fisheries Project	DoF jointly funded by World Bank and FAO	Public awareness and piloting fish passes/aquatic sanctuaries, and fish habitat restoration.	Better use of sluice gates ,developing protocol for the operation that maintains free movement of fish

(Sources: LGED 2005, FFP 2002, WFC 2005, CNRS 2005)

Many projects, such as Fourth Fisheries Project (FFF 2002) of DoF and CBFM of WFC (2005), claimed that there are substantial improvements with respect to habitat restoration and conservation because of the project interventions. Major project interventions include excavation of degraded fish migration routes, helping local fishers to establish access right to fisheries and allowing stakeholders in the decision-making process while formulating development and management. It is claimed by the projects that after the interventions, there have been improvements related to production increment, and an equitable distribution of fisheries benefits (FFF 2002 and WFC 2005). In most of the projects, there has been allocation of funds to carry out development activities at field levels. However, no full mandate has ever given to a fisher community in order to carry out a development program such as canal excavation or *kata* establishment. Rather, in all projects provision has been kept for the community to carry out developmental as well as management activities under the supervision of NGO and/or DoF officials.

At the project level, many degraded canals are excavated to develop the link between habitats, aiding fish migration. However, there is no national policy addressing the fish migration problem caused by flood protection embankments, and no decision has been made so far to open up migration routes in case of severe obstacles such as cross dams. Moreover, there is no resource mobilization at the community level or project level to reopen the migration routes. In this respect, a firm policy commitment is needed to address the issue of the removal of dams and other obstacles in fish migration routes.

CHAPTER 6: POLICY IMPLICATIONS, DISCUSSION, AND CONCLUSION

This chapter discusses the policy implication of the study findings and describes some crucial observations with respect to knowledge related to habitat conservation and restoration. This chapter reviews the result of the thesis objectives and focuses on the relevance of the present study to various fisheries policies of Bangladesh, with the intention to aid future policy decisions related to management of fisheries. As such, it tries to develop a framework of how a shared working environment between scientists and policy makers could be achieved.

6.0 Policy issues of fisheries concerning conservation and management

Fishers and stakeholders each have detailed knowledge with respect to habitat classifications, habitat requirements to life history stages of fish, fish behaviors and impacts of various environmental changes to habitats and livelihoods. This knowledge can be used in habitat restoration and conservation, and in the formulation of policies. Better understanding of the policy processes is fundamental for effectively pursuing sustainable management of natural resources. It can help scientists and managers understand how policy has historically impacted the management of the fisheries resource. In this view, I will highlight basic policy processes/narratives in fisheries management of Bangladesh and the implications of the findings of the study pertaining to existing policies.

6.1 Nature of fisheries policy processes in Bangladesh

Various studies on the policy processes of Bangladesh fisheries highlight that several framings are often articulated in the inland fisheries (Keeley 2003; Parveen and Faisal 2002; Toufique 1997). These studies imply that policies regarding fisheries management are mostly revenue and aquaculture focused. These studies also indicate that there is little room to accommodate various management issues of vast openwater fisheries. In this subsection I highlight some of the important policy narratives concerning fisheries management in Bangladesh.

a) Revenue narrative: This is the oldest narrative and still current. In this narrative, waterbodies are primarily seen as sources of income for the state. It tries to ensure that maximum rents are secured from a given *jalmohal* (waterbody). Some argue however, that the Ministry of Land, which is responsible for collecting revenue, is not as efficient as they might be in this task, and that revenue is collected on an inequitable basis (Keeley 2003). In this approach, the rich benefit and the poor fishers hardly keep any of the revenue that they generate. This approach does not address biological management of the fisheries, nor equitable distribution of the benefits. This approach also brings conflict when dealing with land management in fishing areas. The Ministry of Land remains the sole authority in dealing with *jalmohal* lease management, while the line ministry, the Ministry of Fisheries and Livestock (MoFL), does not have any authority in management in the fishing area (WFC 2003).

b) Production narrative: It is primarily associated with the Department of Fisheries. It revolves around articulation of a serious production crisis being addressed by the application of fisheries science. The goal of fisheries management is to increase production, which is framed primarily as a technical challenge. Stocking programs flow from a preoccupation with production. There are bureaucratic incentives for a scientific management production - oriented approach, including the potential rent-seeking opportunities that may be associated with it, either through manipulation of fish passes, or delivery of fingerlings in stocking programs. It is often argued that stocking programs are imposed on communities with little consultation, and because of this, limited participation is often ineffective.

c) Environmental narrative: Tends to recognize the gradual degradation and shrinking of fisheries resources. The degradation is occurring through encroachment of flood control embankments, conversion of floodplains to agriculture, and loss of habitat. In 1987, the DoF estimated that 1.7 million ha of aquatic habitat would be lost over the next two decades. Flood control structures prevent *beels* and *baors* from connecting to rivers, sometimes having harmful impacts on fish ecosystems and population movements (Ahmed 1999). True intervention with respect to conservation and management of fish habitats, is not yet evident.

d) CBFM narrative: This approach is fairly new and was started in mid 1980s. It combines the equity issues related to livelihood of the poor and sustainability of the resource. It also reinforces the idea of moving from state policing of resources and arrangements that limit access to resources by large parts of local communities, to forms of co-management that can be argued to be a more realistic way of reaching environmental objectives, such as long term sustainability and diversity of fish stocks, and maintenance of the habitats on which they depend. The co-management narrative emphasizes the role of property rights and the importance of working with identifiable local communities which can be facilitated to cooperate with or exclude outsiders regarding sharing benefits. This narrative argues that community can operate with some degree of equity that benefits the poor. It is assumed that communities will deliver environmental sustainability, since they are closer to the resources and have fewer alternatives.

Clearly no one model of CBFM is appropriate for all settings. Many administrators and policymakers still think of fisheries as fish farms or industries that can be made ever more productive, not as renewable, but depletable, natural fisheries in many waterbodies are overstressed and may be close to the point of no return. Inland fisheries resources are widely considered to be in a critical situation with respect to sustainability (Thompson et al. 2000; Mirza and Ericksen 2005). Narratives such as revenue and production seem unsustainable and deserve reconsideration. As result, most of the above policy narratives are highly criticized and the environmental critique makes much of the limitations of a production approach.

6.2 Policy implications of the study

This subsection focuses on some crucial observations with respect to fishers' knowledge of habitat conservation and restoration and reflects on several discrepancies of existing rules and policies with the intent to use the output of the study to influence future policy decision-making. It also reflects on the need for holistic management of some other aquatic resources available in the beel to expand the livelihood income opportunities for rural households.

6.2.1 Fishers' perception on habitat conservation/restoration measures

The interviews with fisheries managers and policy-makers in DoF reveal they are in agreement with conservation/restoration of fish habitats through the establishment of fish sanctuaries and the development of link canals by removal of obstacles which decrease fish production in open waters. In some cases, fishers' responses with respect to conservation/restoration measures, such as removing dykes or excavation of degraded canals, are mixed. Fishers believe that such measures alone could not ensure good fish habitats and uninterrupted migratory routes unless certain measures are put in place. According to fishers' views, a physical connection among habitats could ensure timely in- and outflow of water and help improve the biological and physical environment of a waterbody. Fishers also showed several concerns over linkage management. They pointed out that depending on the nature of operation, creation of connectivity could bring negative impact to fisheries. For example, if the migratory routes are kept open during the early monsoon, it will facilitate timely entrance of floodwater. This is very helpful for fish that spawn early in the monsoon because flood waters carry the eggs into nutrient rich areas such as beels. More importantly, an early arrival of water is responsible for fish that breed at the beginning of monsoon. Early spawners include carnivores such as snakeheads- *shole, boal, taki* and many small fish such as *puti, tengra,* and *baims*. The easy movement of water at the time of recession during late monsoon causes loss to fisheries, it carries the juvenile fish out of their feeding grounds to rivers and reduces the production in the beel area. This happens especially in the years when flood recession starts early, such as in October following the disappearance of monsoon rains. However, recession of water after December is not harmful as growth time for fish is nearly 6-7 months. As connectivity brings both positive and negative impacts to fisheries, precautionary measures should be taken to make fisheries economical. In this respect, fishers prefer controlling devices (such as sluice) to maintain the water level during the recession period (October-December); a permanent solution to the problem so that a harmony between water arrival and recession can be maintained.

According to fishers and fisheries managers, fish sanctuary can play an important role in conserving fish, but strategies are yet to be formulated and tested regarding the applicability of fish sanctuaries and maintenance. Both fisheries and fisheries managers believe that a big sanctuary is more useful, but due to the problems related to the acquisition of bulk amount of land from publicly used beels, very often it is not possible to go for such an intensive program. In that case, a small sanctuary is preferred.

Very often fishers refer to the conservation of different habitat features required for protecting fish during spawning season, as well as in summer when water levels go down. They also point out the best use of non-agricultural lands like road-side canals and burrow-pits as dry season fish refuge. To conserve habitat features, they referred to the conservation of enough water during dry season. In addition, existence of enough water in dry seasons, fishers refer to the need for the presence of aquatic vegetation in the beel area.

6.2.2 Similarity and dissimilarity between scientific and fishers knowledge

The present study discovered that much knowledge related to fisheries is covered both in modern scientific knowledge as well as in local traditional knowledge. However, there are many areas of fisheries where modern scientific knowledge is inadequate and fishers knowledge is more detailed and practically oriented. The knowledge held in both knowledge systems and has specificity to fishers is broadly categorized in Table 14.

Table 14. Possession of knowledge by fishers and scientists

Knowledge types	**Known to both fishers and scientists**	**Specifically known to fishers**
Fish habitat classification	Broadly classified – such as river, beels, floodplains, *baors* (big natural depressions) etc.	Habitat level classification such as *Goheen pani* (deeper waters) and *Chara* (shallow area), which are more effective types of classification with respect to fishing and conservation
Reasons for fish habitat Degradation process	Both fishers and scientists are aware of the reasons for degradation	In-depth knowledge of when they can link the process of degradation with social and environmental factors.
Development intervention and fish habitats	Both fishers and scientists are aware of the adverse effect of road communications	Detailed knowledge of the degradation process and its impacts on such interventions.

(Table continued to next page)

Knowledge types	Known to both fishers and scientists	Specifically known to fishers
	embankment and sluice gates	
Habitat component (vegetations)	No study so far regarding habitat components of fish(e.g. vegetation types required for specific fish)	Fishers have can identify the plants and are aware of the importance of them to fish habitats.
Fish reproductive behavior/spawning of fish	Scientists are mostly aware of carp spawning and the study of other natural fish is greatly ignored (Hussain and Mazid 2001)	Detailed knowledge about reproductive behaviour of the small fish which comprise 90% of the catch (for details see section 3.2 of the thesis).
Hydrological cycle	Catch trends and type of catch	Detailed knowledge about the timing of recession and inflow of water to beel area. In-depth knowledge about the dry season water availability and fish production and linkage of water bodies.
Fishing practices and spectrum of damages	General agreement on *current jal* (gill nets) as harmful fishing method	Disagreed by many and considered seine nets as harmful.
Cause of catch degradation	General agreement on fishing pressure	Many disagreed and mentioned about the habitat loss
Fish production and nutrition	Studies encompass only the changes in the nutritional level (Roos et al. 2003) but no detailed information on the cause and subsequent coping mechanism.	Detailed history of changes in the nutritional level and coping strategies (see section 4.5.2 of the thesis).
Biodiversity	Generalized information on the status of fish biodiversity (IUCN Bangladesh 2000) and does properly indicate the status of a study area	Fishers hold past and present records of fish biodiversity and the historical changes occurring the in the study area (see section 4.5.2 of the thesis)

(*Source: Based on interviews of fishers, scientists and managers and references quoted herewith*)

6.2.3 Habitat loss is responsible for fish decline

In Bangladesh there have been various studies that describe the reasons for fish catch decline (de Graaff 2001; FAP-17 1994). Among the reasons are an increased number of fishers, indiscriminant fishing, over-harvesting, silt congestion in waterways, construction of flood protection embankments, and irrigation and drainage projects for agricultural production and sluice gates are considered as major ones. Very often, it is claimed that the reasons are functioning either in separate or in combination for reduction of fish production from natural waters. Many fishers in the current study agreed that fish catch is declining at an alarming rate; however, many hold a different view with respect to the cause of production decline. During the study, a sample survey was undertaken on fishers' views of fish decline. It showed that slightly more than half of the fishers disagreed that the cause is the increased number of fishers. Rather, about two-thirds agreed that habitat loss is the main reason for reduced fish catch. Their argument carries more weight when they added the issue of fish biodiversity, migration trends and dry season water refuge. Fishers informed that due to habitat loss, migration (spawning, feeding, over-wintering) of fish is impaired.

In many cases, due to siltation many migratory routes are blocked. As a result, migratory fish (e.g. carps and large shrimp) do not enrich the diversity of catch, failing to contribute to natural fish catch. In this regard, the fishers' perception is that if the fish habitats are not reduced due to water scarcity and loss of connectivity, fishing pressure by itself would not damage the resource base -- many fish will be able to escape from the gear being used. The fish would be able to propagate in the next season and the catch will increase. Accordingly, a vast majority of the fishers in my survey agreed that improving the connectivity of fish habitats will help fish regenerate though the facilitation of migration. In this regard, a detailed study is needed to find out the ways that habitats could be saved, especially in dry seasons, and how connectivity among habitats could be reestablished (Rahman and Minkin 2003). Fishers deserve more project investment in improving fish habitats. They believe that if fish habitats are properly protected other components of management measures like reducing fishers and implementation of fish rules would not be so important.

6.2.4 Gill nets are not necessarily harmful

Inland fisheries of Bangladesh are rich in fish diversity. To optimize fishing, a number of fishing techniques have been used historically by the traditional fishers in open waters. In addition to the old gear, there has been introduction of new types of gear. It is estimated that there has been operating 169 fishing gears in land waters. Most of the gear is allowed for fish catch, with some restriction on the operation of fixed engines to waterways (Fish Conservation Act 1950). Under this Act, the fishing of carp under nine inches long, *hilsha* under 12 inches, and several other sillurid fish such as *pangash, silong* and *ayre* under 12 inches, are prohibited during July to December, November to April and February to June respectively. Such fishing in general is carried out using monofilament gill nets, locally called *current jal*. The nets have been in operation since the beginning of the 1970s. Since that time, there had been much opposition to the gear. Considering the magnitude of catch and damaging effects of the gear, the Government of Bangladesh made a decision against the use gill nets in 2001. The implementation of this decision has been held up by a court case.

Even though there has been enough support from general public in implementing the rules to stop the use of such gears, very little progress so far has been made in respect of actual prohibition (Dr. Guasuddin Khan, pers. com.). The decision on banning the use of the gear was challenged by the Fisheries Association of Bangladesh which filed an appeal immediately after the decision was made. As a result, there have been many questions about the usefulness of the ban. The present study reveals interesting information regarding gill nets. It is estimated that about 60% of the local stakeholders and 50% of the real fishers believe that fishing *current jal* is not as harmful as it was originally thought. They argue that a *Current jal* allows fish to grow to a certain size before they are caught. They informed me that it is not because of the *current jal* that the fisheries are declining, but because of small mesh seine nets (locally called "*Kheta ber jal*) that are non-selective do not allow any fish, even the juveniles. Fishing using *ber jal* also greatly damages the fish habitats by uprooting aquatic vegetations. By this argument fishers challenged the existing fish rules that prohibit *Current jal* (Fish Conservation and Protection Act 1950 and Fish Policy 1998). A detailed investigation is required regarding the debates related to fishing gear bans.

6.2.5 Other important uses of beel

Traditionally in the scientific community as well as in the management levels, beels are primarily considered as the main source for fisheries. However, in the rural areas beels have many other uses as well. For example, people in the beel area see beels as good areas for duck raising and as an important source of snails and mussels (called locally *shamuk and jhinuk* respectively). Fresh mollusks are a high quality food for ducks, and the shells are sold locally or exported to other part of the country to be used as ingredients for poultry feed. The beels also provide easier transportation facilities for rural villagers who use country boats to move short distances during the rainy season. Beels are a sources of fodder for cattle. The fertile soils available in beels are used to re-vitalize infertile and degraded farm lands. Beels are also sources of seasonally available wild vegetables (Figure 10) and a source of irrigation water. Given the multiple uses of the beels, local fishers, as well as other stakeholders, have greater expectation beyond considering the beel as a fisheries source. They believe that there is potential for diversification of their livelihood income if effective management policy is formulated and implemented to consider the local situation. However, there is no example for integration of management that ensures multi-use of the beel areas.

a) A local woman is collecting tuber of water lily

b) Displaying collected tubers

Figure 10. View other uses of beel resources

6.3 Conclusion

6.3.0 Revisiting the objectives

Like other developing countries, Bangladesh attempts to ensure fisheries development in a sustainable way. This thesis makes the argument that the application of local ecological knowledge to resource management is vital. A trend is beginning towards using traditional ecological knowledge in recent Community-based Fisheries Management projects of

Bangladesh (MACH 2005; WFC 2005). The rich indigenous knowledge of local fishers related to fish behavior and fish habitats, and their implications for fisheries policy indicate that scientific knowledge alone is not adequate to resolve the problems of the floodplain fisheries of Bangladesh.

Given the above context, the focus of this research was to address the issue of fish habitat restoration and management, primarily within the study area as well as broadly at the national level, to manage the openwater fisheries resources in a sustainable manner. In this context, the knowledge, related to fish habitat management was researched and their relevance to fisheries management was discussed.

The first objective of the research was to identify any local and traditional fisheries knowledge relevant to restoring degraded floodplain fisheries. It was found that fishers are well-versed in fisheries knowledge with respect to fish habitat selection, life stages and the relationship of fish habitat to fish growth, maturation, and migration.

The second objective of the thesis was to identify the role of such knowledge in development and management to target the restoration of degraded floodplain fisheries. In this respect, the research focused upon ascertaining the role of fishers' knowledge in formulating strategies that would be most preferable to the beel fisheries for sustaining the fisheries resource.

The third objective of the study was to investigate policy implications of fishers' knowledge in conservation and management of fish habitats. Many resource users within the study area depend solely on the fisheries resource for their livelihood. There have been some other development interventions with respect to agriculture, housing, and land reclamation affecting the fisheries. In this respect, fisheries resource management is part of an integrated development process and formulating fisheries management would certainly be a policy issue that is based on the broader understanding of the local livelihoods and developmental contexts. Using local traditional ecological knowledge in combination with conventional management is part of the larger development framework.

The study discovered that both fishers and fisheries managers are in agreement on the utilization and sharing of conventional scientific knowledge and traditional fishers' knowledge for better management of natural fisheries. However, it was not fully clear to the parties how information sharing could be operationalized. The study makes several recommendations to answer this question by summarizing the major findings with respect to collective management and integration of local knowledge.

6.3.1 Summarizing the major findings

1. Management of fish habitats in isolation might not be a good way of habitat conservation. Beels in the monsoon season become part of rivers and help fish growth. Rivers protect fish from beels in dry season by giving shelter. Both are important and both should be conserved.

2. Fisheries mangers believe that it is vital to establish the rights of community fishers to access to the fisheries. If their rights could not be established, it will not be possible to bring fishers into modern management systems and the valuable indigenous knowledge will be eroded or lost.

3. Communities, especially traditional fishers, can help fisheries management in a number of ways. They can suggest the appropriate techniques and approaches for constructing a sanctuary. They can suggest which mesh size will be appropriate for conserving some key fish species. They can help to identify the proper time and place for implementing fish rules. They can help provide information on extirpation (local extinction) of fish and the process to restore them.

4. The value of the community people in fisheries management could be acknowledged properly at the policy level if fisheries managers need to ensure good management by the participation fishers. The ongoing community-based fisheries management program should follow the process. For example, community based plantation

programs in Bangladesh where the government and public share the management and share the benefits as well.

5. To ensure participation fisheries managers need to visit the community to build credibility and share views and ideas with the community fishers

6. Many fisheries managers and scientists believe that fishers' knowledge, in various respects, is more valuable than conventional scientific knowledge, so, their knowledge would be well documented and would be conserved and disseminated.

7. When we think of fisheries development, fisheries managers must explore what knowledge fishers already have to restore and develop a particular resource.

8. Fisheries managers, NGOs could help fishers to form groups by revitalizing the local level institutions (such as *samaj*, a village level congregation that was very effective in the past to manage social conflict); to contribute inter-institutional relations and help effectively in resource management systems.

9. From managers and NGO points of view, there could be mass communication describing destructive fishing and the needs of habitat conservation. In this respect visual presentation depicting various damage and restoration aspects of fisheries could greatly help to create understanding for rural fishers.

10. For better use of indigenous knowledge of fisheries by different traditional fisher communities, there is a need to document, preserve and disseminate for better management of openwater fisheries. Bringing fishers' knowledge into regular professional educational curriculum (e.g. text books) can augment the understanding of the value of local knowledge for resources management.

11. The effort for habitat conservation in policy level is scant but there is some hard evidence that advocacy through government and environmental groups has been

actively prohibiting these detrimental activities in natural environment (Pers. comm. with Mr. Anisul Islam, CNRS, and Bangladesh) and help restore fish habitats. It is true that the impact of such initiative in restoration of fish habitats is yet to be recognized.

12. Though sanctuary construction is considered an important step in the conservation of fish habitats, its maintenance process is complicated. It was suggested during the study that in the case of *kua* sanctuary (ditches in a beel basin similar to *kata* sanctuary), some locally adaptable techniques that match the topography of the beel are needed. Construction should be done in such a way that accumulation of water at first precipitations (March-April) in ditches of *kua* sanctuary that carry high loads of silts can be avoided. Rather a process would be formulated to facilitate entry of such water into canal so that siltation process would be slowed down, a big problem in long-term operation of *kua* sanctuary.

6.3.2 Ways of using different kinds of knowledge in policy

Globally, various efforts are underway to protect environment and management of natural resource on a sustainable basis. The modern management approaches with respect to protecting natural habitats, include the creation and conservation of formal protected areas, the restoration of degraded habitats, the creation of new habitats as mitigation measures, and the removal of existing dams from certain water courses (Smokoroski et al.1998; Clifford 2001). Very often such solutions fail to achieve the expected outcomes for many reasons such as lack of participation of the resource users in the management process, proper decision making. Moreover, when seriously scrutinized, they have been shown to be highly cost-ineffective. As a result, there has been a shift in the management of fisheries resources to a broader approach that recognizes fisher's participation, local stewardship, and shared decision-making (Ahmed et al. 2003; Ahmed and Pomeroy 2006). The shift of government-driven management into shared management show a various forms of partnership called co-management (Biswanathan et al. 2003). This partnership has given the opportunities for using fisher ecological knowledge into modern management systems. Various studies argued that there are, nevertheless, proven simple methodologies for creating and enhancing aquatic systems (Welcomme 2002; Berkes et al. 2001). Brush pile fisheries in Asian rivers (known as *kata* in Bangladesh) have traditionally been utilized by small-scale fishers as fish aggregating device around the world. This knowledge and these local techniques sometimes serve as alternatives and cost effective approaches to aquatic resources management in place of, or parallel to, more conventional conservation practices. But in a practical sense, it is a difficult task to bring all parties to work together under a shared vision of management. Therefore, successful management must be cognizant of these views where appropriate and multi-level approaches are to be taken into account which recognizes the interests and impact of related sectors. In this sense, fisheries management cannot function in isolation from the real world through bypassing the policy level of a country. Rather, fisheries management should be a part of a policy where scientific efforts are needed to shape it to support better management.

Efforts could be made to work towards developing a shared vision of sustainable development, or towards a pattern of development that includes ecological integrity. It could be suggested that scientists could put more emphasis on research approaches that promote better management of the natural resource base. Likewise, governments could attempt to shape policies that provide communities and individuals with incentives to use natural resources in a more sustainable manner.

Various studies, with respect to management of natural resources, indicate that almost all research has policy content, but that capturing the attention of policy leaders is a difficult process (Cortner et al. 1998; UNPAN 2000). However, in the wake of worldwide concerns over habitat degradations, increasingly efforts are being made to work towards a shared vision of sustainable development that addresses inherent ecological integrity. As such relations between science and policy concerning issues related to natural resources management have been changing worldwide (Cortner et al. 1998).

Public pressure to resolve such complex and often controversial issues has resulted in policymakers and policy implementers seeking better knowledge on which to base their decisions. As a result, scientists and policymakers have to be more actively engaged in developing policies that help management and sustainability of the resources. In this regard, scientists would put emphasis on research approaches that promote better management of the natural resource base. Likewise, governments would attempt to shape policies that provide communities and individuals with incentives to use natural resources in a more sustainable manner. However, the transformation of this idealistic policy framework is considered premature and policymakers and scientists are expected to be proactive in formulating ways for collective action. In the process to promote more sustainable approaches to managing natural resources, scientists and policymakers should act as natural allies (UNPAN 2000). In such an arrangement, both parties are to perform their particular responsibilities. For achieving common goals with respect to management, there would be opportunity to get access to either party's findings, as well as to activities of the other. As such, scientific result must be translated into effective policies if they are to have an effect on the resource-using community. On the other hand, policymaking should, to the highest extent possible, be based on accurate, timely, and appropriate knowledge and information. Very often, the interface between the two institutions is underdeveloped or it functions poorly.

Perhaps a close working relationship has not evolved between officials in the line ministry such as Ministry of Fisheries and Livestock and fisheries managers and scientists during the past decade. For the researchers, this has meant learning is not enough with respect to the way in which policy processes operate, especially in learning to present results in such a way that policy leaders are able to follow. Involving policy-makers in setting the research agenda for governmental research bodies has proven to be especially effective in establishing policy reform. Bringing research results to the policy-makers through seminars and discussions has also proven effective. Moreover, there is a need to develop a series of policy briefs to convey research results to policy makers. These briefs, written should be in a clear, easy-to-understand fashion, aimed at distilling the policy lessons of highly technical researches.

In many places of the world, the practice of environmental policy making is being transformed into a more open, decentralized, and participatory process which involves local stakeholder groups in discussions over a number management issues (UNPAN 2000) and hold dialogue to bring local knowledge into management . Bringing science into the open, or, in other words, involving scientists in discussions with representatives of local community, as well as Government, would be an important learning process which can help the sustainable management of fisheries.

REFERENCES

Agrawal, A.1995. Dismantling the divide between indigenous and scientific knowledge. *Development and Change* 26: 413-439.

Ahmed, M. Parvin S. and Paul. M.T. and C. K. Chong. 2003. Understanding Livelihoods Dependent on Inland Fisheries in Bangladesh and South East Asia. WorldFish Center, Dhaka. Available at: http://www.worldfishcenter.org/Operational%20Plan/OP2003/PDF/op2003_priap.pdf

Ahmed, N. A., 1999. Fingerling stocking in open waters. *In H. Middendorp, P.Thompson and R. Pomeroy (eds) Sustainable Inland Fisheries Management in Bangladesh. ICLARM Conf. Proc. 58. pp 201-8.*

Ahmed, K. and M. Ahmed. 2002. Fish Sanctuary; necessity, practice and prospects. Technical Assistance for Rural Development, Dhaka. pp.165

Ali, M.O. and M. Ahmed. 2001. *Biodiversity conservation: Vision for Bangladesh. Bangladesh State of Biodiversity*, Ministry of Environment and Forrest, Dhaka, Bangladesh. pp.33-49.

Ali, M L. and Paul M. Thompson. 2006.Wetland protection through sanctuaries in Bangladesh. Draft Technical Paper 4. MACH (Management of Aquatic Ecosystem Through Community Husbandry).

Ali, M. Y. 1997.*Fish, Water and people reflections on inland openwater fisheries resources of Bangladesh.* The university press limited, Dhaka, Bangladesh.

Bao, T. Q., K. Boukhamvongsa, S. Chan, K. C. Chhuon, T. Phommavong, A. F. Poulsen, P. Rukawoma, U. Suornratana, D.V. Tien, T. T. Tuan, N.T. Tung, J. Valbo-Jorgensen, S. Viravong, and N. Yoorong. 2001. Local knowledge in the study of river fish biology: Experience from Mekong. Mekong Department Series No. 1-22 pages.

Bangladesh Gazette. 1995. The Protection and Conservation of Fish (Amendment) Act, 1995.

Bart, A. 2002. Conservation of fish genetic diversity: need for development of a cryogenic gene bank in Bangladesh. In: Proceedings of the Workshop on Genetic Management and Improvement Strategies for Exotic Carps in Asia. Bangladesh Fisheries Research Institute, Mymensingh, Bangladesh. pp.107-110.

Berkes, F. 2004. Rethinking community-based conservation. Conservation Biology 18: 621-630.

Berkes, F. and C. Folke. 2002. Back to the Future: Ecosystem Dynamics and Local Knowledge. In: *Panarchy: Understanding Transformations in Human and Natural*

Systems (Gunderson, L. and C. S. Holling, eds.). Island Press, Washington, D. C., PP. 121-146.

Berkes, F., R. Mahon, P. McConney, R. Pollnac and R. Pomeroy. 2001. *Managing Small-Scale Fisheries: Alternative Directions and Methods.* International Development Research Center, Ottawa.

Berkes, F. 1999. *Sacred Ecology: Traditional Ecological Knowledge and Resource Management.* Taylor and Francis, Philadelphia and London.

Berkes, F. (ed.).1989. *Common Property Resources: Ecology and Community-Based Sustainable Development.* Belhaven Press, London.

Bergmann, M. H., R. R. Hinz, M. J. Blyth, S. Kaiser, I. Roger, and M. Armstrong. 2004. Using knowledge from fishers and fisheries scientists to identify possible ground fish "Essential Fish Habitats". *Fisheries Research* 66: 373-379.

Bergstrom, M. 2004. Review of experiences with and present knowledge about Fish Aggregating Devices. FAO Working Papers- BOBP/WP/23. Available: ftp://ftp.fao.org/docrep/fao/007/ad963e/ad963e01.pdf [accessed April 2005].

Burke, L., S. Liz, and M. Spalding. 2002. *Reefs at Risk in South Asia.* World Resources Institute, Washington, D. C.

Canadian Wildlife Service and Canadian Wildlife Federation. 2003. Invasive alien species in Canada. Available at: http://www.hww.ca/hww2p.asp?id=220&cid=0 [Last accessed: March 2005].

Chambers, R. 1994. Participatory rural appraisals (PRA): analysis and experience. *World Development* 22 (9): 1253-1268.

Colorado, P. 1988. Bridging native and western science. *Convergence* 21 (2-3): 49-67.

Cortner, H.J., M.G. Wallace, S, Burke, and M.S. Moote. 1998. The need to address the institutional challenges of ecosystem management. *Landscape and Urban Planning.* 40: 159-166.

Clark, Roger N.; Meidinger, Errol E. [and others]. 1998. Integrating science and policy in natural resource management: lessons and opportunities from North America. Gen. Tech. Rep. PNW-GTR-441. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p. Available at: http://www.fs.fed.us/pnw/pubs/gtr_441.pdf

Clifford, N. J. 2001. Conservation and the river channel environment. In: *Habitat Conservation: Managing the Physical Environment* (Warren, A., and J. R. John eds.), Willey and Sons Ltd. New York, USA. pp.68-104.

CNRS (Center for Natural Resources Management). 2005. Community Managed Fish Sanctuary Impact on Inland Open Water fisheries. Official Report. CNRS, Dhaka. Pp.24.

de Graaf, G.J., Born, B. Uddin, K.A. and Marttin, F. 2001. Floods Fish & Fishermen: Eight years of experience with floodplain fisheries, fish migration, fisheries modeling and fish biodiversity in the compartmentalization pilot project, Bangladesh. The University Press Limited, Dhaka, 108 pp.

De Walt, B. R. 1994. Using indigenous knowledge to improve agricultural and natural resource management. *Human Organization* 53(2): 123-131.

DoF (Department of Fisheries), Bangladesh. 1998. Fish catch bulletin. pp.28 .

Dudgeon, R. and F. Berkes. 2003. Local understanding of the land: Traditional ecological knowledge and indigenous knowledge. In: *Nature Across Culture: Views of Nature and the Environment in Non-Western Culture,* (Selin, H. ed.), Kluwer Academic Publishers, Dordreht, PP 75-96.

EGIS (Environment and GIS Support Project for Water Sector Planning). 1997. Floodplain Fish Habitat Study. Official Report on Water Resources Planning. Ministry of Water Resources. Bangladesh.

FAO (Food and Agricultural Organization). 2002. *The State of World Fisheries and Aquaculture.* URL: http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/007 /y5600e/y5600e00.htm [accessed March 2005].

FAO (Food and Agricultural Organization). 1999. Information on fisheries management in the people's republic of Bangladesh. Available at: http://www.fao.org/fi/fcp/en/BGD/body.htm. [accessed- May 2005].

FAP (Flood Action Plan)-17. 1994. *Flood Fisheries Studies.* Final Report, Main volume. Flood plan coordination organization, Ministry of Water Resource, Government of Bangladesh, Dhaka.

FARN (Fisheries and Aquatic Resources Node). 2004. Strategic Plan 2004 to 2009. URL: http://far.nbii.gov/documents/FinalFARStrategicPlan.pdf [accessed May 2005].

Farook, M. 1999. Analysis of the legal regime for inland fisheries in Bangladesh. *In*: Sustainable Inland fisheries management in Bangladesh. Proceedings International Center for Living Aquatic Resources Management (ICLARM) 58: pp.37-43.

Faulkner, A. and A. Renato and M. Silvano. 2001. Status of Research on indigenous Fishers' Knowledge in Australia and Brazil. In Proceedings of the conference on "Putting fishermen's knowledge to work" held at the Fisheries Centre, University of British Columbia, August 27-30, 2001, pp 110-116.

FFP (Fourth Fisheries Project). 2005. Semi-Annual report. Department of Fisheries, Dhaka. pp 85.

Fish Policy Bangladesh. 1998. Ministry of fisheries and live stocks. Bangladesh.

Freeman, M.M.R., Y. Matsuda and K. Ruddle (eds.). 1991. *Adaptive Marine Resource Management Systems in the Pacific*. Harwood Academic Publishers, Philadelphia, Tokyo, Melbourne.

Freeman, M.M.R. and L. N. Carbyn (editors). 1988. *Traditional Knowledge and Renewable Resources Management in Northern Regions.* Occasional Paper No. 20, Boreal Institute for Northern Studies, Edmonton.

Freeman, M. M. R. 1992. The nature and utility of traditional ecological knowledge. *Northern Perspectives* 20(1): 9-12.

Gadgil, M., P.Olsson, F. Berkes, and C. Folke. 2003. Exploring the role of local ecological knowledge in ecosystem management: three case studies. In *Navigating Social-Ecological System: Building Resilience for Complexity and Change* (Berkes, F., J. Colding, and C. Folke, eds.), pp.189-209.

Gallagher, C. 2002. Traditional Knowledge and Genetic Discrimination of Lake Lipigon Lake Trout Stock. Masters thesis. Natural Resources Institute, University of Manitoba Canada.

Grant, S. and F. Berkes. 2004. "One Hand Cant Clap': Combining Scientific and Local Knowledge for Improved Caribbean Fisheries Management." Presented at "The Commons in an Age of Global Transition: Challenges, Risks and Opportunities," the Tenth Conference of the International Association for the Study of Common Property, Oaxaca, Mexico, August 9-13.

Grenier, L.1998. Working with indigenous knowledge. A guide to researchers. International Development Research Center, Ottawa.

Grumbine, R. E. 1994. What is ecosystem management? *Conservation Biology* 8:41-47.

Hardin, G. 1968. The tragedy of the commons. *Science* 162: 1243-1248.

Holling, C. S. 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems* 4: 390-405.

Holling, C.S. and G. K. Meffe. 1996. Command and control and the pathology of natural resource management. *Conservation Biology* 10: 328-337.

Hughes, R., S. Adnan and B. Dalal-Clayton. 1994. *Floodplains or Flood Plans? A Review of Approaches to Water Management in Bangladesh.* IIED, London.

Hussain, M.F.A. Mollah, G.U. Ahmed. 2002. Effect of Diazinon 60 EC on *Anabas testudineus, Channa punctatus* and *Barbodes gonionotus.* Naga, The ICLARM Quarterly, Vol. 25, No. 2: 8-12.

Hussain, M.G. and M.A. Mazid. 2001. Genetic Improvement and Conservation of Carp Species in Bangladesh. BFRI and ICLARM publication, Dhaka, Bangladesh. pp.44

IUCN Bangladesh. 2000. Red Book of Threatened Fish of Bangladesh/edited by Mahmud-ulAmeen, Md. Anwarul Islam and Ainun Nishat. Bangladesh, IUCN – The World Conservation Union, xi, 116 p.

Jackson. D. C. and G. Marmulla. 2001. Dams, fish and fisheries Opportunities, challenges and conflict resolution. FAO Fisheries Technical Papers - T4. URL: ftp://ftp.fao.org/docrep/fao/004/Y2785E/y2785e.pdf [accessed May 2005].

Jepson, P. and R. J. Whittaker, 2002. Histories of protected areas: Internationalization of conservationist values and their adoption in The Netherlands Indies. *Environment and History (*8), 129–172.

Johannes, R.E., M.M.R. Freeman, and R.J. Hamilton. 2000. Ignore fisher's knowledge and miss the boat. *Fish and Fisheries* 1: 257-271.

Johnson, M. 1992. Dene traditional knowledge. *Northern Perspectives* 20(1): 3-5.

Kabir, M. I. and S. A. Khan. 2004. Management of fish sanctuaries: legal options. The National Holiday. A Bangladesh Daily internet version. Available at: http://www.weeklyholiday.net/2004/250604/env.html.

Kapoor, I. 2001. Towards participatory environmental management? *Journal of Environmental Management* 63:269-279.

Kelso, J.R.M., and C. Wooley. 1996. Introduction to the international workshop on science and management for habitat conservation and restoration strategies (HabCARES). *Can. J. Fish. Aquat.Sci.*53. (Suppl.1.): 1-2.

Keeley, J. 2003. Policy Processes for Community Based Fisheries Management in Bangladesh: Lessons for Change. Available at: http://www.ids.ac.uk/ids/bookshop/LESS/BANGLAFISHERIES.pdf

Khan, N. A. 2000. Popular wisdom, popular lives. In: *Of Popular Wisdom: Indigenous Knowledge and Practices in Bangladesh.* BARCICK, Dhaka. PP 1-3.

Konar, S.K. 1975. Pesticides and aquatic ecosystems. Indian J. Fish. 22(1&2): 80-85. Rahman, M.Z. G. Hussain, M.F.A. Mollah, G.U. Ahmed. 2002. In : Effect of Diazinon 60 EC on *Anabas testudineus, Channa punctatus* and *Barbodes gonionotus.* Naga, The ICLARM Quarterly, Vol. 25, No. 2: 8-12.

Korten, David C., and Norman N. Uphoff. 1981. "Bureaucratic Reorientation for Participatory Rural Development."National Association of Schools of Public Affairs and Administration, Washington, DC. (Working Paper, no. 1).

Levi-Strauss, C. 1966. *The Savage Mind.* Weidenfield and Nicholson, London.

LGED (Local Government Engineering Department) Bangladesh. 2005. Small-scale water resources development. Interim Report. LGED Dhaka.

Ludwig, D. 2001. The era of management is over. *Ecosystems* 4: 758–764.

MACH (Management of Aquatic Ecosystem Through Community Husbandry). 2003. *Project Completion Report.* Vol.1: 84. A project of the Government of Bangladesh Supported by USAID Project Partners: Winrock International Bangladesh Centre for Advanced Studies (BCAS) Center for Natural Resource Studies (CNRS) CARITAS Bangladesh.

MACH (Management of Aquatic Ecosystem Through Community Husbandry).2005.Semi-Annual Report. A project of the Government of Bangladesh Supported by USAID Project Partners: Winrock International Bangladesh, Centre for Advanced Studies (BCAS), Center for Natural Resource Studies (CNRS) CARITAS Bangladesh

Mamun, A. M. 2005. Pictorial guide on inland fish of Bangladesh. WorldFish Center, Dhaka. pp.92

McKim, J. M., D.A. Benoit, K.K. Biesinger, W.A. Brungs and R.E. Siefert. 1975. Effects of pollution on fresh water fish. J. Wat. Pollut. Contr. Fed. 47: 1711-1764.

Minkin, S. F. and J. K. Boyce. 1994. Net losses: "development" drains the fisheries of Bangladesh, *Amicus Journal*, 16 (3): 36-40.

Mirza, M. Q. and Neil J. Ericksen. 2005. Impact of water control projects on fisheries resources in Bangladesh. *Environmental Management.* Volume 20 (4): 437-593

Mitchell, B., 2002._*Resource and Environmental Management,*_2nd edition, Harlow, Prentice Hall, 367 pp.

Mitland, P. S., and N. C. Morgan. 1997. *Conservation Management of Freshwater Habitata Lake Rivers and Wetlands.* Kluwer Academic publishers, Boston/ Dordrecht/ London.

Moyley, P. B., and G. M, Sato. 1994. On the design of preserves to protect native fish. In: *Battle Against Extinction: Native Fish Management in American West* (Minckley, W. L., and J. E. Deacon, eds.), The University of Arizona Press, Tucson, pp. 155-169.

Morgerum, R.D. 2001. Organizational commitment to integrated and collaborative management: matching strategies to constraints. *Environmental Management* 28 (4): 421– 431.

MPO (Master Plan Organization) Bangladesh.1997. *Openwater capture fisheries resources.* 1987. Technical report 18.pp. 72.

Nadasdy, P.1999. Politics of TEK. Power and the "integration" of knowledge. *Artic Anthropology* 36 (1-2): 1-18.

Neis, B., T. Pitcher and R. Johannes, eds. 2001. *Putting Fishers' Knowledge to Work.* Oxford: Blackwell Science.

Neis, B., L. Felt, D.C. Schneider, R. Haedrich, J. Hutchings, and J. Fischer. 1996. Northern cod stock assessment: what can be learned from interviewing resource users? *DFO Atlantic Fisheries. Research document* 96/45, 28 p.

Pandey, D. N. 2003. Traditional knowledge systems for biodiversity conservation. URL: http://www.infinityfoundation.com/mandala/t_es/t_es_pande_conserve.htm [accessed May 2005].

Parvin, S. and M. F. Islam. 2002. Open-water Fisheries in Bangladesh: A Critical Review. Available at: http://www.lars2.org/unedited_papers/unedited_paper/Parveen.pdf

Pomeroy, R.S., and Ahmed, M. Fisheries and Coastal Resources Co-management in Asia: Selected Results from a Regional Research Project. WorldFish Center Studies and Reviews 30, 240p. Available at: http://www.worldfishcenter.org/resource_centre/Fisheries&Coastal_1.pdf

Poulsen, A. F. 2001. Integration of fishers' ecological knowledge into research on a large tropical river basin, the Mekong River in Southeast Asia. Paper presented at the conference Putting Fishers Knowledge to Work', UBC Fisheries Centre, Vancouver, BC, pp. 198-207.

Pinkerton, E. 1994. Local Fisheries Co-Management: A Review of International Experiences and Their Implications for British Columbia Salmon Management. Canadian Journal of Fisheries and Aquatic Sciences, 51(10): 2363-2378.

Pretty, J. and D. Smith. 2004. Social capital in biodiversity conservation and management. *Conservation Biology* 18: 631-638.

Primack, R. B. 2002. *Essentials of Conservation biology.* Sinauer Associates, Inc., Saunderland, Connecticut, 3rd edition, 163-174.

Rahman, M.Z. G. Hussain, M.F.A. Mollah, G.U. Ahmed. 2002. Effect of Diazinon 60 EC on Anabas testudineus, Channa punctatus and Barbodes gonionotus. Naga, The ICLARM Quarterly, Vol. 25, No. 2: 8-12.

Rahman, M. and S. F. Minkin. 2003. Net Benefits: The Ecological Restoration of Inland Fisheries in Bangladesh. Paper presented in international conference of natural resources. Held in Tagaytay City, the Philippines.

Rahman, A. 1989. Freshwater Fisheries of Bangladesh. Bangladesh: Zoological Society of Bangladesh, C/O Department of Zoology, Dhaka University, Dhaka, Bangladesh.

Roos, N., M. M. Islam and S. H. Thilsted. 2003. Small Indigenous Fish Species in Bangladesh: Contribution to Vitamin A, Calcium and Iron Intake. J. Nutr. 133(11). Available at: http://jn.nutrition.org/cgi/reprint/133/11/4021S. [accessed: October 2006].

Richards, P. 1989. Farmers also experiment: A neglected intellectual resource in African science. *Discovery and Innovation* 1(1): 19-25.

Saunders, D.L., J. J. Meeuwig, and A. C. J. Vincent. 2001. Freshwater protected areas: Strategies for conservation. *Conservation Biology*, 16(1): 30-41.

Schusler, T. M., D.J. Decker and M. J. Pfeffer. 2003. Social learning for collaborative natural resources management. *Society and Natural Resources*, 15: 309-326.

Scoones, I., M. Melnyk, and J. Pretty.1992. The Hidden Harvest: Wild foods and agricultural systems. London. Sustainable Agricultural Program. IIED.

Sillitoe, P. 2000. State of indigenous knowledge in Bangladesh. In: Indigenous Knowledge Development in Bangladesh: Present and Future, ed. The University Press Limited, Dhaka.

Simpson, R. L. 1999. Construction of Traditional Ecological Knowledge: Issues, Implications, Insights. Ph.D. Thesis, University of Manitoba, Winnipeg, Canada.

Slocombe, D.S. and P. Dearden. 2002. Ecosystem-based management and park planning, pp. 295-320 in P. Dearden & R. Rollins, eds., *Parks and Protected Areas in Canada*, 2nd ed, Oxford University Press, Toronto.

Smokorwski, K. E. K. J. Withers, and J. R M. Kelso. 1998. *Does Habitat Creation Contribute to Management Goals? An Evaluation of Documented Freshwater Habitat Rehabilitation or Enhancement.* Canadian technical report of fisheries and aquatic Science, Department of Fisheries and Ocean. Great lakes laboratory for fisheries and aquatic science, ON, Canada.

Thé, A. P. G. and N. Nordi. 2004. Common Property Resource System in a Fisheries of the Sâo Francisco River, Minas Gerais, Brazil. Presented at The Commons in an Age of Global Transition: Challenges, Risks and Opportunities, the Tenth Conference of the International Association for the Study of Common Property, Oaxaca, Mexico, August 9-13.

Thompson, P.M. 2003. Understanding livelihoods dependent on inland fisheries in Bangladesh and Southeast Asia. DFID/FMSP Project R8118. Bangladesh Summary report. Retrieved from:http://www.ahj00.dial.pipex.com/r8118/r8118_13.pdf [Accessed May 2005].

Thompson, P. M., Sultana, P. and M. N. Islam. 2000. "Cooperation, Conflicts and Sustainability in Community-Managed Fisheries in Bangladesh." Presented at "Constituting the Commons: Crafting Sustainable Commons in the New Millenium", the Eighth Conference of the International Association for the Study of Common Property, Bloomington, Indiana, USA, May 31-June 4.

Thompson, P. M. 1997. Social and distributional issues in open water fisheries management in Bangladesh. Papers presented at the FAO/DFID Expert Consultation on Inland Fisheries Enhancements Dhaka, Bangladesh, 7–11 April 1997. Available at: http://www.fao.org/docrep/005/W8514E/W8514E25.htm#ch23

Toufique, K. A. 1997. Some Observations on Power and Property Rights in the Inland Fisheries of Bangladesh. World Development, 25(3), 457-467.

UNEP (United Nations Environment Programme). 1992. Rio Declaration on Environment and Development. Available at: http://habitat.igc.org/agenda21/rio-dec.htm.

UNESCO .2004. Best practice on indigenous knowledge. Retrieved from: http://www.unesco.org/most/bpikpub.html [accessed May 2005] .

UNPAN (United Nations Online Network in Public Administration and Finance). 2000. The Interface between Natural Resource Management Research and Policy Change. Available at: http://unpan1.un.org/intradoc/groups/public/documents/idep/unpan002348.pdf

Viswanathan, K.K., J.R. Nielsen, P. Degnbol, M. Ahmed, M. Hara and N.M. R. Abdullah. 2003.Fisheries Co-management Policy Brief: Findings from a Worldwide Study. WorldFish Center Policy Brief 2, 26 p.

WFC (WorldFish Center, Bangladesh). 2005. Fourth output to purpose review report. Official report. World Fish Center, Dhaka, Bangladesh, 80 pp.

WFC (WorldFish Center, Bangladesh). 2004. Fish sanctuary and habitat restoration program .Community Based Fisheries Management Waterbodies, Bangladesh. WorldFish Working paper no.18. World Fish Center, Dhaka, Bangladesh, pp.40.

WFC (WorldFish Center, Bangladesh). 2003. Annual Report. Community-based fisheries management project (Phase-2). World Fish Center, Dhaka, Bangladesh, pp. 165-175

WFC (WorldFish Center, Bangladesh). 2003. Records of household survey on *Gharani* working areas (Unpublished). WorldFish Center, Dhaka.

Warren, A., and J. R. French (eds). 2001. *Habitat Conservation: Managing the Physical Environment.* John Willey and Sons Ltd. New York, USA. pp.1-5.

Warren, D.M., L. J. Slikkerveer, and D. Brokensha. 1999. Introduction. In: *The Cultural Dimension of Development: Indigenous Knowledge Systems,* eds, Intermediate Technology Publications, London, ixv-xviii.

Welcomme, R.L. 2002. An evaluation of tropical brush and vegetation park fisheries. *Management and Ecology* 9: 175–188.

Welcomme, R.L.1985. River fisheries. Local knowledge in the study of river fish biology.Experience from Mekong. FAO Fisheries Technical Paper no. 262: 1-330.

Wolfe, J., C. Bechard, P. Cizek and D. Cole. 1992. *Indigenous and Western Knowledge and Resource Management System.* University School of Planning and Development. University of Guelph, Ontario, Canada.