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A green horizontal band with silhouettes of people and a heart. The silhouettes are in a darker shade of green, and the heart is a lighter shade. The background of the band is a medium green color.

## Experiences in wetland co-management – the MACH Project

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## ABSTRACT

Since 1998 the Management of Aquatic Ecosystems through Community Husbandry (MACH) project has established what is best described as community based co-management of three large wetland systems covering in total about 32,000 ha (about 4,600 ha of water in the dry season). The project is supported by USAID and the Government of Bangladesh and implemented by Winrock International, CNRS, Caritas and BCAS working closely with Department of Fisheries and Ministry of Fisheries and Livestock. The key elements of the MACH approach have been establishing community organizations and then embedding within them institutions for sustainable wise use of wetland resources, formally linking these with the existing local government system, and through this making interventions to restore wetland productivity and improve the livelihoods of the poor. The organizations involved comprise: 16 Resource Management Organizations representing all local people with interests in wetlands and fisheries, 13 Federations of Resource User Groups comprising of poor fishers and other poor wetland users, 25 Union Parishads, and the administrations of 5 Upazilas. Co-management is formalized through Upazila Fisheries Committees where representatives of all bodies sit to coordinate and oversee management of the systems.

The results of these organizations observing closed seasons, excavating about 46 ha of beels and 30 km of canals to expand dry season water holding, establishing 56 sanctuaries of 173 ha area and planting 605,000 trees include increases in fish catches of 2-5 times over 1999 baselines of 58-171kg/ha, reaching 316-388 kg/ha across the whole wetland systems in 2004-05, and increases in fish consumption of 45% over the same period which benefit the landless as much as large landowners. Revolving loan funds worth US\$ 0.42 million (Tk.29.10 million) have been transferred to community organizations along with training and have helped about 5,200 poor households increase their supplemental incomes by about 50% while also reducing their dependence on fishing by about two-thirds. For sustainability the Upazila Fisheries Committees are being endowed with a total of US\$ 0.53 million (Tk 36 million), the interest from which will primarily be used for continued restoration of wetland habitat by the Resource Management Organizations. A catchment and wetland ecosystem approach has been vital – for example tree planting and the promotion of contour cultivation on hills have aimed at reducing soil erosion and siltation of wetlands. Ability to address threats has been enhanced, for example in Kaliakoir the number of textile related industries increased from 20 in 2003 to 166 in late 2005 and surface water is now far below national standards in the dry season. The communities now have their own water quality monitoring program and the Upazila Fisheries Committee and Department of Environment have agreed to sign an agreement to cooperate to enforce existing anti-pollution laws as a priority.

MACH has also supported the Department of Fisheries (DoF) to take up similar activities in some of the Fourth Fisheries Project sites, and to assist the new inland capture fisheries team of the department. The MACH approach has already been taken up at the policy level. The Inland Capture Fisheries Strategy of the DoF incorporates as a key element establishing Upazila Fisheries Committees nationally to incorporate and work with an expanding network of community based organizations, and also places the spread of permanent sanctuaries and efforts to restore and sustain major wetlands as high priorities.

## INTRODUCTION

In Bangladesh about four million hectares of land are inundated every year in the monsoon (rainy) season, and over half the country is under water in an exceptional flood year (Ali 1997). In the dry season, the wetlands reduce in size to form a system of rivers, beels (depressions and lakes that hold water permanently or seasonally), and baors (oxbow lakes).

The floodplains of Bangladesh are one of the world's most important wetlands and home to hundreds of species of fish, plants, birds and other wildlife. The wetlands provide the habitat for over 260 fish species (Rahman, 1989) and hundreds of thousands of migrating birds (BirdLife International 2004), and are an important source of income and nutrition for millions of households in rural Bangladesh, particularly the poor. As many as 80% of rural households catch fish for food or to sell (FAP 16, 1995) and about 60% of animal protein consumption comes from fish (BBS, 1999). In addition, poor and marginal households catch many small fish that are not included in official statistics or policies, and use aquatic plants and animals for food or as feed for livestock.

Unfortunately, the wetland resources of Bangladesh are in decline due to over fishing and loss of habitat and connectivity. Wetlands in the past were thought to be "wastelands" in Bangladesh and the Government's goal was to drain out and "recover" them for agriculture production (albeit for one crop a year during the dry season). Even in areas that have not been converted to agriculture, wetland ecosystems have been threatened by other pressures:

- Flood embankments and water control structures have blocked many fish migration routes.
- Irrigation has expanded winter rice cultivation but reduced the surface water that aquatic life needs to survive in the six-month dry season.
- The government leases out fishing rights in public water bodies, but short-term leases have encouraged maximum exploitation without giving incentives to protect resources for the next generation.
- Industrial development causes severe local pollution that kills breeding fish populations during the dry season, residual pesticides and agro-chemicals also adversely affect wetland habitat.
- Deforestation and poor land management cause high rates of siltation, often filling in dry season wetlands that serve as fish holding habitat during a crucial time of the year.
- More and more people fish destructively by dewatering or using fine mesh nets.

The decline in wetlands has resulted in more than 40% of freshwater fish species being classed as threatened with national extinction (IUCN Bangladesh 2000). Since 1985, natural carp spawn catches have declined by 75% (Ali 1997) and major carp and large catfish have declined by 50% in national catches. Fish consumption fell by 11% between 1995 and 2000 (but by 38% for the poorest households), and it is estimated that inland capture fisheries catches had fallen by 38% between 1995 and

2002 (Muir 2003). Despite recent changes in national policies that call for an end on drainage of remaining wetlands (MWR 1999), wetlands continue to be encroached for agriculture, industry, brickfields and aquaculture with no sign of abatement.

The Management of Aquatic Ecosystems through Community Husbandry (MACH) project was formulated to develop new approaches to floodplain and wetland resource conservation and management with the aim of ensuring the sustainable productivity of all wetland resources – water, fish, plants and wildlife– over an entire wetland ecosystem (comprising beels, seasonal wetlands, rivers and streams), not just a single water body and thereby to help ensure food security and increase biodiversity. The MACH project started in October 1998 and is due to be phased out between June 2007 and June 2008. The project is supported by USAID and the Government of Bangladesh and implemented by Winrock International, Centre for Natural Resource Studies (CNRS), Caritas-Bangladesh and Bangladesh Centre for Advanced Studies (BCAS) working closely with Department of Fisheries and Ministry of Fisheries and Livestock.

## MACH SITES

Hail Haor is located in north-east Bangladesh and is typical of deeply flooded basins in that region known as haors. It lies between the Balishara and Barshijura Hills to the east and the Satgaon Hills to the west. Water from these hills flows through 59 streams (once 350 were reportedly active) into the haor. The haor is located in five unions<sup>1</sup> of Srimangal Upazila and in two unions of Sadar Upazila of Moulvi Bazaar District. The watershed of Hail Haor covers about 600 km<sup>2</sup> (237 square miles). Hail Haor was formerly connected by Gopla River and Kamarkhali Khal with the Kushiya and Manu Rivers. A series of flood control dikes along these rivers and a sluice gate restrict river flows and fish access to the haor. The wet season area of Hail Haor is approximately 14,000 ha, whereas the dry season area is typically just over 3,000 ha on an average. Approximately 172,000 people live in 61 villages around the haor.

The Turag-Bangshi site is located just north of Dhaka and is typical of most low-lying floodplains of Bangladesh. The project site covers seven unions of Kaliakor Upazila under Gazipur District and one union of Mirzapur Upazila of Tangail District. The Turag-Bangshi River runs. At the beginning of the rainy season, water spills over the riverbanks through khals (canals) that connect the river to the adjacent beels. Fish move through these canals from the river to the beel/floodplain areas for spawning or nursing, and then later as water recedes after the monsoon the fish move into the deeper perennial portions of the beels or back into the river. Dry season water levels in the local rivers and beels are much reduced from their former levels due to the vast expansion of ground and surface water extraction for boro (dry season) rice irrigation. Fish remain only in the deepest portions of the beels and the river. The 26 beels have a water surface of approximately 10,000 ha at full flood, which diminishes to less than 700 ha at the end of the dry season. The Turag River runs for

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<sup>1</sup> A Union is the lowest administrative level in Bangladesh, typically there may be about 10 unions in a sub-district or Upazila. An elected council or Union Parishad governs each union comprising of representatives from the 10 or so villages within a union.

approximately 30 km through the site and there are another 28 km of canals. Approximately 225,000 people live in 226 villages that make use of the river and floodplains.

The Kangsha-Malijhi site is located in north-central Bangladesh in Sherpur Sadar and Jhenaigathi Upazila of Sherpur District. The area is geographically a part of Garo-Tura Hills watershed and includes the catchments of the upper Kangsha and Malijhi river system. The hills of this area were once covered with natural Sal Shorea robusta forest; now only remnants of natural forest remain. The wetlands and floodplain have a water area of approximately 8,000 ha during the wet season, which diminishes to about 900 ha in the dry season. The floodplain area contains 47 beels or low pockets, of which 18 are perennial. The population of the area is approximately 279,000 in 163 villages. The area is prone to flash floods with water coming from the hills and damaging crops before draining away. Continued flood damage to the monsoon crop has forced farmers to shift to cultivating more dry season boro. The resulting increase in extraction of surface and ground water for irrigation poses a threat to wetlands and the environment in general during the dry season.

## INSTITUTIONAL APPROACH

Like several projects in Bangladesh in the past decade (Thompson et al. 2003; Thompson 2005), MACH has worked to establish community based management systems and has drawn lessons from this. In addition to community organizations for the sustainable use and management of fish and wetland resources, MACH has also worked to improve the livelihoods of poor wetland users and to empower them in decision making. The key differences are:

- The Resource Management Organizations (RMOs) established to protect and sustain wetland resources represent all stakeholders.
- Separate organizations of poor people – Federations of Resource User Groups (FRUGs) – have been formed to help diversify and enhance their livelihoods.
- These community based organizations (CBOs) have been formally linked with local government (both Union Parishads – elected local councils, and Upazila or sub-district administration) through Upazila Fisheries Committees.
- Separate partner NGOs have worked to support each of these types of body and their activities in a collaborative and coordinated way.

### **Resource Management Organizations**

Resource Management Organizations (RMOs) were organized around wetland management areas that contained recognizable dry season water areas or systems (typically identifiable through a local name) but this followed a process of initial understanding, planning, and working in smaller parts of those areas with the communities. The RMO comprises of villagers – fishers, farmers, landless, local elites, men and women – who serve as representatives of the community, chosen from those living in and around the wetland management area and using its resources. The RMO is responsible for the management of the wetland resource

including identifying appropriate management interventions through participatory planning, and implementing them.

The project approach to form local organizations and institutions adopted the following general sequence of steps:

1. Conduct introductory meetings with the Upazila and Union Parishad to introduce MACH and sensitize all levels from officials to villagers about the importance of fisheries and other wetland wildlife and plants.
2. Identify the communities' wetland resource problems and possible solutions including management and physical interventions through the use of participatory approaches.
3. Identify potential management units – these comprise the wetland areas and water bodies and their associated villages and resource users – that are most interlinked and could form a unit to be covered by one local organization.
4. Build rapport and raise awareness in the communities within each management, and post community organizers employed by the project to the sites – one per management unit.
5. Develop the institutions – this was done in a flexible way with important differences in approach between sites. It included working with the representatives from the area who form the general body of the RMO to select from among themselves their Executive Committee and discuss and agree on their constitution.
6. Register RMOs with the Social Welfare Department, thereby giving the RMOs a legal entity and status as local non-government organizations.
7. Develop the capacity of the RMOs and their members, for example how to run the organization, plan activities, supervise implementation, and introduce wetland resource management norms to their areas.
8. Work with the RMOs to enhance representation of the poor and of women by revising RMO membership to ensure a majority of representatives of poorer people dependent on the wetland resources based on 60% of members being representatives of the Resource User Groups (RUGs) formed separately by the project, and associated changes in constitutions to strengthen and protect the interests of poor people.
9. Implement an exit strategy to ensure that the RMOs are sustainable based on: adoption of guidelines on financial and natural resource management, annual review and agreement of resource management plans developed by the RMO in consultation with the wider community and government, and building offices for each RMO.
10. Conduct twice yearly reviews of RMO performance and status to guide capacity building and phasing out.

It was key that the project took a flexible approach in the development of local institutions. The project staff considered the physical characteristics of the wetlands, the settlement of communities around the resource, pre-existing property rights (such as leases) to the wetlands and the social characteristics of the users. This required a high level of capacity in field based staffs that facilitate the process, and places stresses on project management.

The Turag-Bangshi (Kaliakoir) wetlands have a number of lower deeper pockets of water (locally known as kur or kum for rivers and doha for beels). These are the key

hot spots for the fishery since they become isolated water bodies in the dry season and hold the remaining fish stock. The rest of the area is seasonally flooded and comprises private crop land. Separate committees of local people from nearby villages were established to protect certain kums and dohas as sanctuaries, as agreed through participatory planning. Later RMOs were formed covering larger wetlands – the beel or river that is a common flooded area in the monsoon and contains several kums and dohas. All members of these kum and doha committees became general members of the RMO, resulting in relatively large organizations bringing together people each trying to protect their local part of a connected wetland resource system, and with the executive committee of the RMO coordinating and overseeing the activities of the constituent kum and doha committees.

In the fishery of Hail Haor (Srimangal) most of the main dry season water bodies are larger and are jalmohals (state property where the government leases fishing rights to the highest bidder) and are distant from the many user villages that surround the haor. Here the project directly organized stakeholder representatives including local community leaders from those few villages covered by participatory planning into eight RMOs spread around the haor edges. The project then worked to have the leases for some of the jalmohals (one or more in each RMO area) reserved for that RMO without competitive tendering. The RMO then functioned as an enlightened leaseholder sub-contracting fishing to fishers and establishing best wetland management practices in these jalmohals and the neighbouring floodplain.

In Kangsha-Malijhee (Sherpur) area the wetlands comprise of distinct beels that are separate for most of the year. Organization development started by inviting all households in each of the main villages using a given beel system and identified by the project team in its reconnaissance visits to a village meeting, there they formed village committees. These were short lived. Four Participatory Action Plan Development (PAPD) workshops were held one each for two beel complexes and two for the largest wetland area. These formed the basis for the four RMOs that were formed with representatives from the user villages invited to the PAPD and later forming a core group for the respective RMOs.

In total, 16 RMOs have been formed, each covering from 2 to 20 villages, each with populations ranging from 555 to 1,580 households. Based on the choice made by villagers, the members of the general body of RMOs range from 40 to 173 people. The general members selected executive committees ranging in size from 13 to 21. The general body members wanted relatively large executive committees to ensure participation of all villages. Because of the nature of the wetland, under the four RMOs in Turag-Banshi site, there are 20 constituent smaller area based committees (responsible for a deeper pocket within the wetland – a river section or daha), and in Kangsha-Malijhi site there are 18 village committees. At Hail Haor there are no such area based committees within the RMO.

### **Federations of Resource User Groups**

The project recognized from the outset that to restore wetlands and then ensure that they are only used at sustainable levels involves limits on access and use, for example closed seasons and sanctuaries prevent people from fishing as they had done. Moreover the remaining wetlands, even with some excavation, are a finite

resource that cannot provide a decent living for increasing numbers of fishers and a growing population.

To develop alternative livelihood sources for the poor and provide access to micro-credit, small groups were formed, called "Resource User Groups" (RUGs), of 15 -30 men or women from poor households. Generally they own under 0.2 ha of land or less, labour for part of the year, have under 8 years of education, do not belong to any other NGO's groups, and were involved in fishing or collecting other aquatic resources for income or food. Following normal NGO practice for credit and savings programs in Bangladesh, only one person per household could join a RUG, membership is based on making regular personal savings in weekly group meetings. On the basis of savings the members could propose income generating activities for receiving loans. The members also discussed wetland management in their meetings and were trained in business and enterprise skills that they then used after taking loans. Typical enterprises include raising livestock, small shops, and individual skilled work such as tailoring or operating a tree nursery. By late 2006, 5,203 households had members belonging to 250 RUGs. Of the RUG members about 64% are men, about 75% own under 0.2 ha of land.

The MACH approach to livelihood support linked with fishery and wetland management was unique because the RUGs are overlapping but separate from the RMOs. About 60% of the volunteers who belong to the RMOs come from the RUGs and represent the interests of their respective RUGs when they attend the RMO. Similarly wherever there is a RUG in the villages using one of these wetlands it has a representative in the respective RMO.

For the RUG members, the project focused on developing skills and enterprises that would enable participants to reduce their fishing effort or even leave fishing altogether. This included providing vocational training (for example as electricians or drivers) and in some cases providing larger loans of up to Tk 35,000 (US\$ 500). As a result, 153 participants started new skilled jobs or invested in enterprises that provide full time work (for example a power tiller or medium scale broiler chicken farming raising batches of 500 or more chicks).

Activities to benefit the poor were linked to technical interventions such as establishing tree nurseries or trials of alternative crops with lower dry season water demand in an attempt to reduce abstraction from dry season water bodies. However, these initiatives have been scattered and achieving changes in agriculture on a larger scale that is linked up with resource management planning by RMOs for water and land use still has a long way to go.

Federations of RUGs (FRUGs) have been formed roughly coinciding with Union Parishad boundaries (13 in all). These have been registered with the Social Welfare Department. So far the revolving loan funds provided under the project have been transferred to nine of these FRUGs. The FRUGs then have responsibility for managing the savings of their members and credit funds from which they lend to their members. As such they are entirely membership based organizations with elected office bearers from among the members. They already employ staff (paid from part of the interest charged on the loans) to manage the saving and loan

processes, reporting to the executive committee and to the general body of members.

By late 2006 the RUG members had accumulated savings averaging Tk 1,600/member (US\$ 23/member) equivalent to a total of Tk 8.35 million or over US\$ 120,000, and had revolving loan funds of about Tk. 29.10 million (US\$ 427,000). Revolving funds amounting to Tk.16.20 million have been handed over to nine FRUGs, and the remaining amount is due to be handed over to the other FRUGs when they can be registered. For up to one year some FRUGs have been running their micro-credit functions by themselves with limited external supervision and monitoring.

According to a survey undertaken in 2002 the average household income of the RUG participants at that time was about Tk 35,000 (US\$ 540) during the previous year (below the national poverty line of Tk 45,000 (US\$ 690) per household per year). The net profit for borrowers after repaying their loans was Tk 2,150 (US\$ 33) per loan. A sample survey in 2006 indicated that 47% of RUG member households had not earlier fished for an income, but of the 53% that had been professional fishers, 66% had left the profession since joining a RUG and getting support for alternative occupations.

### **Co-management bodies**

Co-management has been a focus of attention in fisheries (and natural resources) management in the last two decades. The IUCN defines co-management as: “*a situation in which two or more social actors negotiate, define and guarantee amongst themselves a fair sharing of the management functions, entitlements and responsibilities for a given territory, area or set of natural resources.*” (Borrini-Feyerabend et al. 2000).

In the case of fisheries it has most often been taken to mean a sharing of responsibility between government and fishing communities. Co-management stretches from government dominated decisions at one end of the range with government instructing users, through consultations, to at the other extreme users advising or informing of their decisions for government endorsement (Berkes 1989; Pomeroy and Williams 1994; Sen and Nielson 1996).

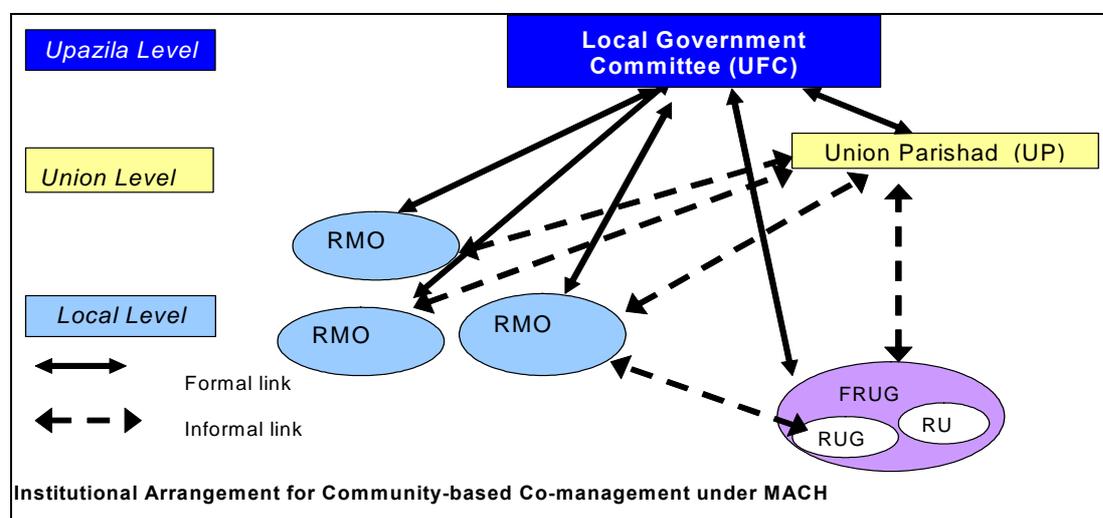
Co-management has been promoted in the belief that a shift from top-down management to sharing decisions and responsibility between resource users and government would improve the quality of decisions and local compliance with management plans. Therefore the intention of co-management is to empower fishers both as an end in itself and in the expectation of better management (Viswanathan et al. 2003). This requires major changes in institutions, organizations and attitudes.

The MACH approach can be termed community-based co-management. It has focused on helping communities organize for improved management of their resources (RMOs) and helped the poor organize to improve their individual livelihoods (FRUGs). But community based management of wetland resources is unlikely to be sustained without recognition from and linkages with other formal institutions, and strong community organizations are needed if wetland users are to

share decision making with government. The MACH project has developed and demonstrated a combination which is new for Bangladesh and has proved very effective. Although the project has been undertaken by NGOs, and has focused on establishing RMOs and FRUGs, they have been formally linked with local government.

By reserving use rights to water bodies for 10 years for community based organizations – RMOs – the government recognizes the right of those RMOs to make and implement management plans and sets of rules just as leaseholders have done in the past. The difference is that with long term rights and considering their community interest, the RMO adopts better practices that sustain and restore fish stocks and wetland biodiversity. In this approach wetland resource management decisions are taken by the RMOs, but these are endorsed, coordinated and overseen by a co-management body. Two tiers of local government are relevant. The Union Parishad is a local elected council typically covering around ten villages, and is the only long standing form of representational local government in Bangladesh. Among its responsibilities is local planning. The Upazila or sub-district is staffed by technical officers of various line agencies as well as administrative officers, and has responsibility for delivering government services.

MACH established Local Government Committees (LGCs) (renamed as Upazila Fisheries Committee - UFC in 2007) in the four main Upazilas where it is working. These comprise of the relevant Upazila officers (chaired by the chief administrative officer – Upazila Nirbahi Officer – and the member-secretary is the Upazila Fisheries Officer), the chairmen of those Union Parishads where wetland management is being improved, and the chairpersons of the community organizations established through MACH – the RMOs and FRUGs. The committees meet quarterly to discuss the problems and potential solutions to wetland degradation, plans for habitat restoration by RMOs are debated and approved, and problems and issues encountered by the community organizations and project have been discussed and solutions found. Originally a mechanism for coordination of project implementation, these have become effective co-management bodies and have been formalised beyond the project end. In addition to this formal co-management body, the RMOs have developed informal links with the Union Parishads in whose areas they work, and are invited to attend the Union Parishad meetings.



## Fig 1. Institutional Arrangements for Community-based Co-Management under MACH

Thus both formally and informally the networking and social capital of the community based organizations have been enhanced through co-management committees playing this supportive role. Local government has a well defined and more substantial role than under the previous system. Figure 1 shows the linkages involved. The LGC/UFC can also refer issues that are outside of its scope to resolve either to the appropriate line agency, such as the District Fisheries Officer, or to the District administration.

To sustain these institutional arrangements beyond the MACH project, MACH has raised awareness within the Government of Bangladesh of the merits of the LGCs as co-management committees. The Department of Fisheries has now proposed that this arrangement be made permanent and extended (eventually to all Upazilas) by establishing Upazila Fisheries Committees with the same composition as the LGC and with both the responsibilities of the MACH LGCs and those of the former Upazila Jalmohal Management Committees (which were concerned only with leasing of some jalmohals). The great merit of this framework is that although it is a uniform prescription, it is for coordination and oversight. Within this framework community based organizations of any and all forms that are effective in improving wetland management and community participation can be supported, just as already the nature of the RMOs under MACH differs between the three sites.

## RESOURCE MANAGEMENT

### Planning and problem analysis

Participatory planning took place in different forms in each site. Initially workshops were used to work with the communities to identify problems and develop potential solutions in Hail Haor and Turag-Bangshi sites. By 2001, in Sherpur the project made use of a more systematic approach, Participatory Action Plan Development (PAPD), that works separately and jointly with stakeholders (see Sultana and Thompson, 2004) and building on earlier methods. The main problems identified in all three sites were siltation and declining fish catches along with losses of other aquatic biodiversity (Table 1). Site specific problems included pollution in Kaliakoir, flooding in Sherpur, and leasing of jalmohals in Srimangal. The physical interventions identified through consensus typically included establishment of sanctuaries, habitat restoration and improvement, and connectivity restoration.

**Table 1 Top seven problems identified by stakeholders in participatory planning**

Problem	Hail Haor	Kaliakoir	Sherpur	Addressed by MACH
Siltation	√	√	√	YES
General decline in fish	√	√	√	YES
Loss/catching of fish spawn and brood fish		√	√	YES

Pollution		√		YES
Use of destructive gear	√	√	√	YES
Leasing system	√			YES
Loss of water birds	√			YES
Decline in aquatic resources plants/ animals	√			YES
Some fish species lost			√	YES
Lack of employment		√		YES
Low water in dry season/ irrigation problem	√			YES
Rice seed (HYV) quality		√		NO
Fish disease			√	NO
Flood damage			√	NO

Based on the outcomes of participatory planning, each RMO developed and agreed upon a set of rules or norms regarding fishing within those areas where it directly controls access or has direct influence<sup>2</sup>. These have been formalized into resource management plans with associated maps and are endorsed by the Upazila Fisheries Officer (UFO). The main access limits introduced by RMOs to ensure sustainable fisheries are:

- aquatic sanctuaries,
- closed seasons of various lengths for all fishing in the early monsoon to protect fish when they are breeding, and,
- bans on fishing gears and activities that have been identified with the local communities to be most harmful to the fishery and wetland – such as dewatering and pumping out of deeper parts of the lakes (beels) and ditches, and use of fine mesh nets that target juvenile fish.

In order to cover costs of water body leases, maintenance of conservation measures and RMO operations, they collect payments for fishing from fishers that just cover these costs.

## Sanctuaries

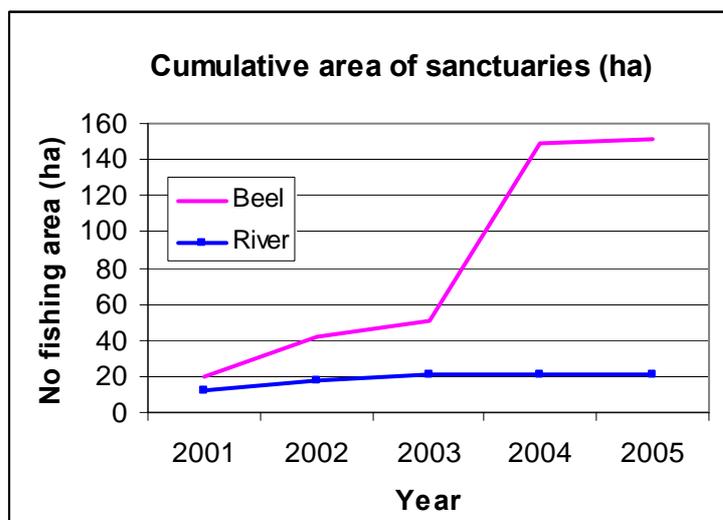
By agreeing to stop fishing year round in areas that retain water in the dry season, the community ensures that adult fish can survive the dry season to breed (and the RMO establishes a general closed season at that time to improve the chances of spawning and juvenile fish). Expected benefits include higher catches in the rest of the wetland system, and restoration of biodiversity including fish, plants, invertebrates and waterbirds. By the end of 2005, MACH had helped RMOs

<sup>2</sup> By 2005 the Ministry of Land had reserved 34 jalmohals for management by the 16 RMOs for 10 years on condition that they pay the government a lease fee each year, a further 8 had been set aside permanently by the government to be sanctuaries protected by the communities. In addition the RMOs influence resource use in private lands that are seasonally flooded which surround these jalmohals, and also in Hail Haor they aim to influence the practices of the leaseholders of other jalmohals.

establish 56 functioning wetland sanctuaries at the three sites covering 427 acres (173 ha) (Figure 2). The sanctuaries are either locally declared or declared by the Ministry of Land.

Locally declared sanctuaries have been set up by RMOs within part of the water bodies (jalmohals) where they hold the fishing rights for 5-10 years. These sanctuaries are part of local management plans and are designed to restore fish catches for the local communities represented by the RMO. Typically they are a small but vital part of the water body that retains water through the dry season and overall cover about 1.9% of the dry season water area of the MACH sites.

A few sanctuaries have been declared directly by the Ministry of Land, after proposals made by the project. These are larger areas of national importance to protect wetland habitat, fish and other aquatic fauna and flora. They have been taken out of the leasing system permanently, and on payment of a nominal fee to government the respective RMO is entrusted by the government to protect the sanctuary. In the Turag River three deeper spots were declared as sanctuaries in this way and function in a similar way to those established just by the RMO. However, in Hail Haor a much larger sanctuary known as “Baikka Beel” that in effect covers a contiguous area of about 100 ha has been established to serve as a wilderness refuge for the whole haor to protect fish, wildlife (water birds) and restore haor wetland habitat.



**Fig.2. Sanctuary areas in rivers and beels under the MACH project**

The project has adapted traditional fish aggregating practices to increase fish populations in sanctuaries. Traditionally local landowners use tree branches to make brush piles in deeper parts of a water body to provide shelter for fish. Algae, plankton and other organisms grow on the surface of these tree branches and become a source of food for fish, and the branches prevent unwanted fishing, then the owner contracts specialist fishing teams to encircle the shelter, remove the branches and catch all the fish. However, tree branches rot and have to be replaced regularly which contributes to loss of tree cover, so in beel sanctuaries the project has installed over 23,000 “hexapods” and pipes made of concrete which will last for many years and serve the purpose of providing shelter, surfaces for growing fish

food and preventing fishing without repeated investments by the RMOs or reducing local tree cover.

### Habitat restoration

Siltation of canals and beels is a major problem that results in a reduction in the volume of water stored in beels. In 1999 it was found that the largest chora (hill stream) feeding Hail Haor carried over 200,000 m<sup>3</sup> of sediment just in July. In 2001, silt loads of 22 choras were monitored – they carried 50,000 tons, suggesting that the total of 59 active choras carry over 100,000 tons of silt into Hail Haor each year. Moreover sediment traps showed deposition of 8-15 cm of silt in one year near the outfalls of the choras, which results in an average estimated raising of the haor bed by about 5 cm per year or 1 m in 20 years (MACH 2004). With only 2-3 m of water in most of the Haor in the monsoon, Hail Haor is changing rapidly, the fringes of the haor are rapidly filling in, and it could disappear as we know it today. This pattern is repeated in the other project sites and throughout the country. The connecting channels or khals between beels and rivers are silting up, and this has a disproportionate impact on the fish populations. Some species of fish breed in the river environment and then juveniles migrate from rivers to beels at the onset of the rains when water levels are rising, later adults return to the river at the end of the monsoon when water levels fall. Blockage of connecting canals by siltation and sluice gates delays or prevents migration of both adult fish and offspring.

To address this adverse trend, wetland habitat has been restored by re-excavating canals to improve flows, and re-excavating beels (mostly within areas declared by the RMOs as sanctuaries) to increase the depth to maintain water year round. The improved habitat provides better shelter for fish, and facilitates breeding and regeneration of aquatic plants and animals.

RMOs and local government formed Project Implementation Committees to oversee contractors and in some cases employ the labourers required for earthworks. Though the total area excavated is modest compared with the total dry season water area (Table 2), these deeper fish refuges and canal connections directly serve and link with the majority of the dry season water area in the three sites.

**Table 2. Re-excavation in MACH Project sites between 1999 and 2005**

Site	Canal length (m)	Beel area (ha)	Area of directly connected water bodies (ha)
Hail Haor	11,200	13.9	211.0
Turag Bangshi	9,500	20.8	144.6
Kangsha Malijhee	9,240	11.1	147.3
Total	29,940	45.9	502.8

Re-excavation of wetlands addresses the outcome of the siltation process but not the root causes. MACH introduced a watershed approach to address water catchment management on a pilot and demonstration basis, this has worked in upland areas that are outside of the wetland and RMO managed areas to address problems identified by the communities. Land use mapping for two chora catchments flowing into Hail Haor revealed that 46% is under tea estates (which are already

reasonably well managed to limit soil erosion), 28% is forest land under the responsibility of the Forest Department (some of which has poor tree cover), and 13% is privately managed pineapple and lemon gardens. The pineapple disproportionately contributed to siltation because the growers habitually grew pineapple in rows running up and down the slope, accelerating soil erosion in this high rainfall area (2,200 mm pa; MACH 2004). Lemons are more typically grown at the base of the hills and not on the steep slopes. By bringing in expertise on pineapple growing and working with a few farmers to test and demonstrate it was found that contour cultivation was not only feasible but resulted in denser planting per ha, reduced fertilizer costs, and generated higher profits (an extra Tk 130,000 (US\$ 2,000) per ha), and of course reduced soil erosion. By the end of 2005, a total of 32 farmers had adopted the contour planting method on 72 plots covering 92 acres (37 ha), and the Department of Agricultural Extension has agreed to promote this method more widely.

Communities felt it was important to plant native trees to mitigate the past trend for loss of tree cover including swamp forest in the wetlands and riparian areas, this is also expected to help reduce the sediment loads in small rivers and channels flowing into the wetlands through bank stabilization. Notably the project has helped to pioneer and demonstrate nursery raising and planting out of native wetland trees - Hijal *Barringtonia aquatungula* and Koroch *Pongamia glabra* – that are adapted to being inundated by a meter or more of water for up to half of the year. This swamp forest is important for providing habitat for growing fish during the monsoon as well as habitat for other wildlife, and helps to shelter villages and provide branches for brush piles. Table 3 summarizes the extent of reforestation through the project. However, out of the trees planted about 293,000 were found to be surviving in late 2006.

**Table 3 Wetland and other reforestation undertaken by MACH up to November 2005.**

Site	Swamp forest (no. trees)	Riparian plantation (no. trees)	Other plantation (no. trees)	Total (no. trees)
Hail Haor	72,105	52,053	59,028	183,186
Turag Bangshi	18,057	59,692	46,304	124,053
Kangsha Malijhee	34,803	121,543	141,780	298,126
Total	124,965	233,288	247,112	605,365

## IMPACTS

### Fish Catches

The management practices adopted by the communities are based on their own problem and solution analysis complemented by specialist biological and engineering expertise, but from the outset (the baseline pre-intervention year of 1999) a rigorous monitoring program was set up to quantify impacts. Fishing catch and effort are recorded at 10-day intervals in 23 fixed monitoring locations covering 1,825 ha and representing the range of wetland habitats present. Within those defined areas separately operating fishing units (which may be one or several

people) were recorded according to the equipment (gear) they used for fishing. For three fishing units of each gear type or 10% of units of that type (whichever was the higher figure) the gear type and characteristics, expected duration of fishing, and catch by number and weight of fish were recorded. The sample area catches are taken to be representative of the whole wetland system and the total catch estimate for the sample areas multiplied up by the fraction of the total area gives an estimate of total catch.

Compared with the baseline years (the first year of records for each site, when there were no management interventions) there have been substantial increases in total fish catch and in catch per hectare in all three sites (Table 4). The greatest gains in catch per area (5 times increase) have been at the Turag-Bangshi site where the fishery was in a very poor condition before restoration. Although effort appears to have increased to a very high level there, catch per person day has also increased. The low levels of catch per person day in both Turag-Bangshi and Kangsha-Malijhee sites reflect the greater importance of subsistence fishing in floodplains in these sites – as this is a supplement to income more people fish for just part of a day or spend days fishing when they have no other work, whereas most of those fishing in Hail Haor do it for their daily income. A complication to interpretation of the trends is that 2004 was a high flood year with greater availability of fish and hence effort increased to take advantage of this bounty. Despite this increase in effort, the catch per person day was higher in 2004 in all three sites than in the baseline year suggesting that the project has resulted in improved fisheries which may be sustained in the future.

Achieving compliance with the fishing norms introduced through the resource management plans has not been easy, and the RMOs have tended to concentrate on water bodies where they hold fishing rights and have had less influence on other areas. Although there is generally relatively little fishing in the months when a closed season was introduced, there is no sign of any overall reduction in effort in that time. However, they do appear to have changed opinions to some extent regarding use of fishing gears and practices identified as particularly harmful. The percentage of effort using such gears has fallen, although total effort with these gears remains substantial. Hence it seems more likely that sanctuaries, excavation of habitat, and the ban on de-watering that RMOs observe may have had the greatest impacts.

**Table 4 Changes in fish catches in relation to wetland management activities in MACH sites.**

Year and site	Maximum area inundated (ha)	Cumulative area of sanctuaries (ha)	Cumulative area excavated (ha)	Total estimated catch (t)	Effort (person days per ha)	CPUE ** (kg/person day)	CPUA *** (kg/ha)	Effort in closed season		Effort with banned gears	
								person days	% of effort	person days	% of effort
Hail Haor											
1999-2000*	NA	0	6.65	2,137	120.8	1.13	171.1	8,896	5	62,853	36
2000-2001	12,214	5.65	10.28	2,561	93.3	1.76	205.0	12,682	9	42,447	31
2001-2002	12,215	8.87	20.30	2,382	89.6	1.71	190.8	15,601	12	40,640	31
2002-2003	14,926	18.11	31.94	3,588	78.1	2.95	287.3	7,979	7	32,592	28
2003-2004	13,490	103.79	70.35	2,021	72.0	1.80	161.8	11,093	11	31,572	30
2004-2005	15,835	103.79	70.37	4,854	138.3	2.25	388.6	21,706	11	57,128	28
Turag Banshi											
1999-2000*	NA	0	0	253	217.3	0.27	57.8	4,290	5	24,917	30
2000-2001	NA	22.34	2.37	546	397.5	0.31	124.7	16,896	11	62,960	41

2001-2002	NA	44.48	4.91	458	491.7	0.21	104.8	37,856	20	31,473	17
2002-2003	NA	44.48	6.12	613	500.4	0.28	140.1	11,855	6	36,797	19
2003-2004	4,297	54.59	34.72	1,379	509.3	0.62	315.2	19,665	10	41,237	21
2004-2005	NA	54.59	39.92	1,403	717.2	0.45	320.7	24,102	9	68,378	25
Kangsha-Malijhee											
2000-2001*	NA	5.69	1.69	1,233	568.6	0.23	150.2	12,838	7	20,416	12
2001-2002	14,926	6.77	9.69	1,225	651.0	0.20	149.2	21,578	11	45,074	23
2002-2003	NA	9.56	21.27	2,244	996.9	0.24	273.4	49,141	16	54,063	18
2003-2004	NA	11.61	46.04	2,591	754.9	0.37	315.6	27,874	12	27,631	12

\* Baseline (no interventions to improve wetland or its management).

\*\* Catch per unit effort

\*\*\* Catch per unit area

Notes: 1. Assumes core closed season is Baishak – Ashar i.e. 17% of the year.

2. Only banned gear considered here is current jal

3. Maximum area inundated is calculated using GIS and a digital elevation model for Hail Haor each year, but has only been estimated once for each of the other two sites.

4. The actual excavated areas are shown and do not include the total area of water bodies within which perennial water areas were created.

## Fish Consumption

It is well known that fish is the main source of dietary animal protein in Bangladesh, but national fish consumption declined between 1995-96 and 2000 by 14% to 11.1 kg/person/year (Muir 2003). To assess direct impacts of improved wetland management on livelihoods, especially those of poorer people, fish consumption was monitored for a panel of 1,050 households from 29 villages. Local women were trained as monitors and visited each sample household once every three days (10 days per month) to sort and weigh the species of fish being prepared for cooking and home consumption.

**Table 5. Fish consumption (g/person/ day)**

Year	Hail Haor	Turag-Bangshi	Kangsha-Malijhee
1999	49	29	Na
2000	52	28	Na
2001	54*	30	24
2002	60**	37**	28*
2003	58**	47**	29*
2004	65**	48**	34**

Notes: 1. Hail Haor and Turag-Bangshi “1999” data are from September-October to April of following year, subsequent years are May to April of next year; Kangsha-Malijhee data covers full calendar years.

2. Figures are averages of each household’s average consumption in the period.

\* = significantly higher than baseline consumption, \*\* significantly higher than both baseline and 1<sup>st</sup> impact year, t-test, p<0.05

In both Hail Haor and Turag-Bangshi fish consumption has gradually increased since the baseline year, and in 2004-05 was respectively 33% and 66% higher than the baseline period (Table 5). These benefits have been shared widely across poor and better off households. Most of the households monitored were landless (about 60%) or marginal farmers (about 20%).

In Hail Haor these were the types of household that have enjoyed significantly higher fish consumption since 2002-03. The other landholding households have not significantly increased fish consumption and since the larger landowners had higher consumption at the baseline this means that the poor have caught up in their consumption. However, this was a more productive fishery even before MACH started its work compared with the other two sites and so fish consumption was much higher than the other sites and the national average.

In Turag-Bangshi all landholding categories had similar levels of fish consumption before the project and all have gained significantly. The timing of increases in fish consumption in the three sites is indicative of a project impact since sanctuaries and excavation only started to be implemented in 2001 so impacts in the next year might be expected.

Households in Kangsha-Malijhee had the lowest fish consumption levels of the three sites initially and this remains the case, but all landholding categories have made similar gains, and even after one year of project activities consumption increased significantly compared with 2-3 years in the other sites. Per capita fish consumption was 33g/day in impact year-3, up from 22 g/day during the baseline period. Per capita fish consumption of landless households increased by 45% and for large farm households by 47%. Similar gains of 46-61% were found for the other landholding classes.

### **Biodiversity**

Fish species diversity was assessed as a simple count of species recorded from the sampling program, which was a constant effort between years in each site. There was at best a modest increase in the number of species recorded between the baseline years and subsequent years (Table 6). The dominant species by weight caught in all three sites included Jat puti *Puntius sophore* which is typical of open waters in Bangladesh. Small shrimps were the highest percentage of catch (10-19%) in baseline and subsequent years in Turag-Bangshi and Kangsha-Malijhee sites. This is a concern, as de Graff et al. (2001) have argued that a high proportion of shrimps in floodplain catches indicates a fishery that has been severely damaged as it lacks appropriate conditions for breeding and recruitment of larger and beel resident fishes.

**Table 6. Fish species diversity (number of species recorded)**

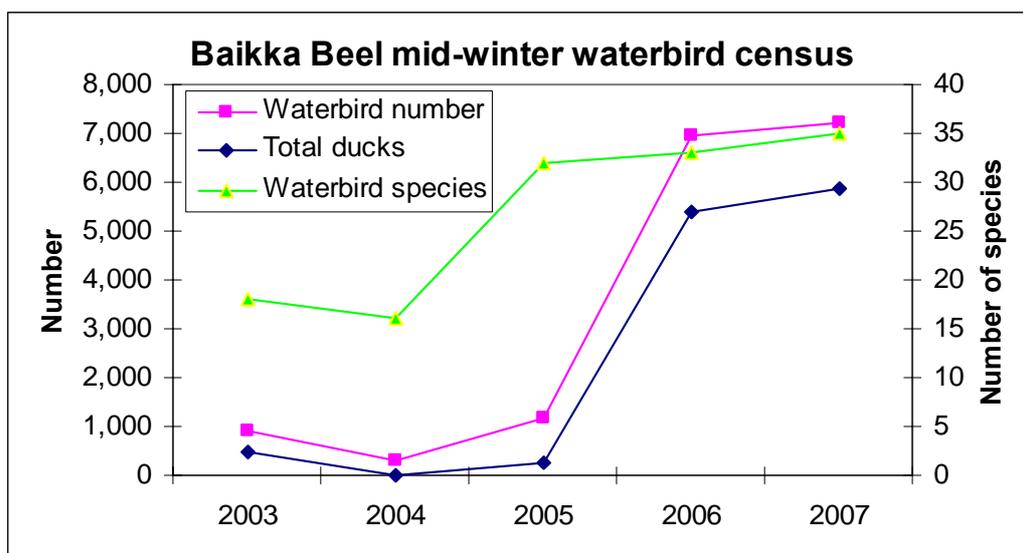
Year	Hail Haor	Turag-Bangshi	Kangsha-Malijhee
1999	71	82	Na
2000	71	81	Na
2001	69	86	64
2002	79	91	67
2003	67	85	71
2004	81	85	73

Years defined as follows: Hail Haor - April to March of next year; Turag-Bangshi - May to April of next year; Kansha-Malijhee - August to July of next year.

In all three sites in the baseline year miscellaneous small fish of a number of species comprised a high proportion of the catch. In the less degraded fisheries (Hail Haor and Kangsha-Malijhee) the recovery has mainly been of other fish such as snakeheads and small catfish able to over winter in the sanctuaries. In Turag-Bangshi while those species groups have recovered, small fishes have also increased substantially in catches.

At the species level, variation in number of species recorded in the surveys reflects observation of some species in one year, but not the other year. However, combining all impact years, in Hail Haor, 96 species have been recorded and species diversity has been maintained or increased during the Project. The pattern is similar in Turag-Bangshi Site where overall 97 species were observed. In Kangsha-Malijhee 88 fish species was recorded in the impact years, a relatively greater gain in species diversity which may reflect initiatives there by RMOs to reintroduce locally rare or lost species as well as conservation measures.

Not only fish have been the focus of wetland management and protection. Tree planting has of course directly restored local plant diversity particularly where swamp forest had been lost. But in Hail Haor in the 100 ha wetland sanctuary of Baikka Beel, since 2004 the RMO has banned fishing, hunting, and collection of aquatic plants, except for limited grazing in part of the area. Since then 111 species of birds have been recorded. Both numbers and diversity have increased, reaching 7,200 birds of 35 water bird species in January 2007 (Figure). These include large flocks of wintering ducks, also six globally threatened and seven near-threatened species have been recorded, including up to six Pallas's Fish Eagle.

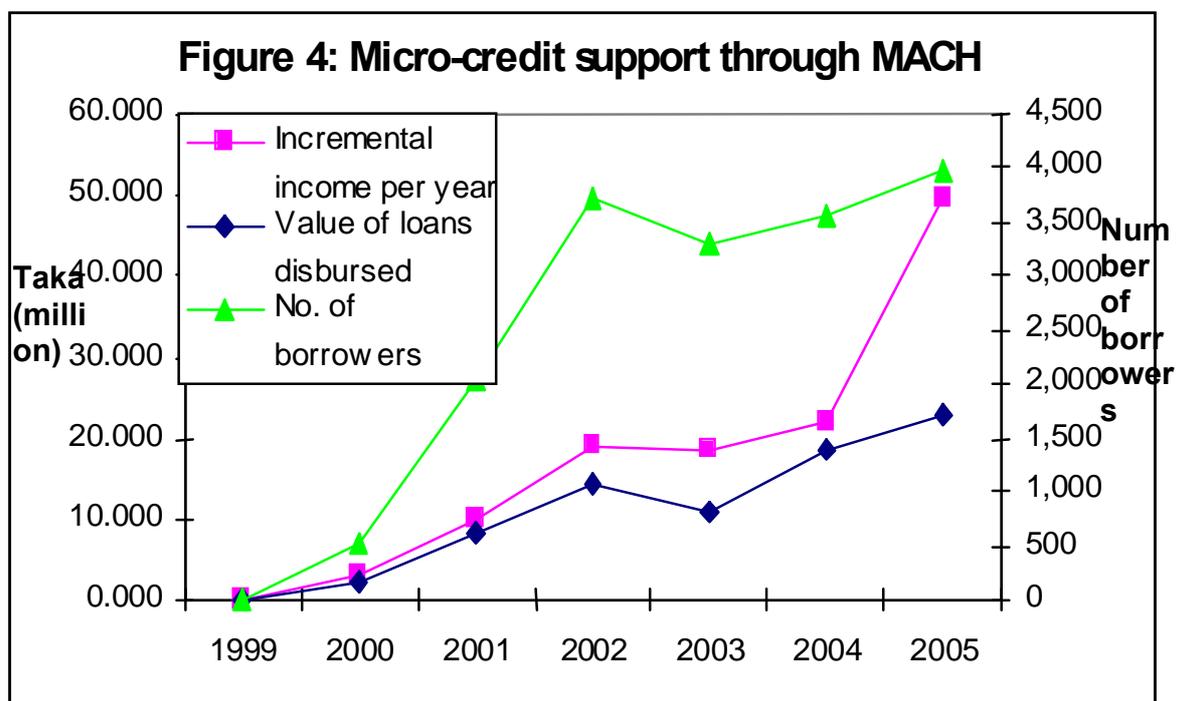


**Fig.3. Bird numbers in Baikka Beel**

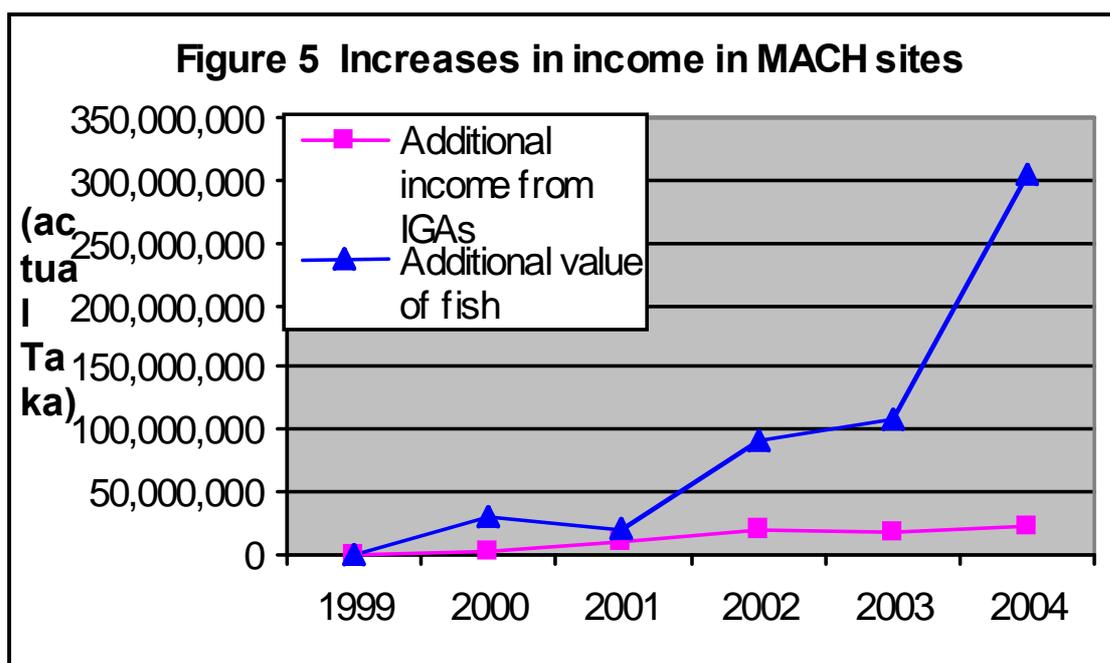
## Livelihoods and Human Capital

Over 5,500 of the poorest wetland resource users have joined savings and credit groups. These have helped the fishing communities refrain from fishing in protected areas and during critical fish spawning periods by providing training and credit to take up alternative income generating activities. This has helped reduce excess fishing, enabling fishing households to take up new enterprises such as poultry and livestock, or skilled employment as mechanics and electricians. Borrowers have substantially reduced their fishing effort. By 2005 almost 4,000 families had increased average income by about 65% over their previous reported incomes (Figure 4). Some were able to leave fishing, while others could reduce fishing during conservation closure periods while still increasing their incomes.

Fishers in the MACH project sites gained US\$ 4.7 million in 2004 (Figure 5) from higher catches associated with resource management improvements, as compared with baseline data from 1999. In addition, by 2005, those participating in training and credit activities earned an extra US\$ 0.8 million, mainly from new enterprises supported by the project, as compared with their pre-participation incomes (daily incomes rose from about US\$1 per day in 1999 to US\$1.34 per day in 2005). This primarily impacted the poor who are most dependent on aquatic resources. Over 85% of households in the project areas are involved in fishing, and all of those supported with training and credit were low income households owning less than 0.2 ha of land, and therefore the poor have benefited the most from the project impacts.



**Fig.4. Micro-credit support through MACH**



**Fig.5. Increases in income in MACH sites**

### **Governance and Social Capital**

The formalization of community-based organizations of resource users has helped to sustain impact and enhanced empowerment. The leaders of both RMOs and FRUGs are elected by ballot, and are responsible to their general bodies through quarterly meetings, and more widely through village meetings. The leaders of these organizations now sit along with local government officials and councillors in UFCs that oversee wetland management. For sustainability the Upazila Fisheries Committees are being endowed with a total of US\$ 0.53 million (Tk 36 million), the interest from which will primarily be used for continued restoration of wetland habitat by the Resource Management Organizations, as well as to cover the operations of the committees.

This system means that there are checks and balances between community organizations, Union Parishad and Upazila officials over the way they function, make decisions and use their funds, while the long term funding arrangement will maintain a focus for continued improvement and restoration of wetland habitats in these large systems. Savings and credit groups are now federated into 13 legal entities – registered membership-based social welfare organizations with elected leaders who also sit on the co-management committees. Moreover in a landmark policy decision, the government has permanently set aside eight “national” sanctuaries to protect wetland biodiversity that are managed by the community organizations. The government no longer auctions out fishing rights in these sanctuaries. The Department of Fisheries, through its national Inland Capture Fisheries Strategy is in process of adopting these institutions and the sanctuary approach on a larger scale as part of a policy shift towards community based co-management.

## THREATS, SUSTAINABILITY, AND POLICY

### Water quality threats

The experience of wetland management has not been all positive in MACH. One of the biggest industrial clusters in Bangladesh is located in Kaliakoir north of Dhaka, where there are many textile and dyeing factories. The communities reported that these industries use the surrounding wetlands, particularly Mokesh Beel and Ratanpur Khal, which flows through the beel, as a disposal ground for untreated waste, resulting in poor catches of bad smelling fish. Effluent from industries downstream in the Turag catchment also appears to be entering the river and is carried upstream during low river flows by tidal effect. As a result, water quality has deteriorated to a level which is unsuitable for certain types of aquatic life.

Regular monitoring results indicated that water in the beel and khal has biological oxygen demands twice the national acceptable standard and chemical oxygen demands four times higher than acceptable standards. Water also has seasonally high pH levels, and sulphide concentrations that averaged 50% above the national acceptable standard but peaked at five times that level (Table 7). High concentrations of heavy metals such as chromium were also found in surface water close to the industries, although aquatic plants were found to absorb some of this pollution such that sediments were within European permissible levels, the possible effects of animal and human consumption of these plants is now known. The problems were traced to local textile related industries which were found to be inefficient – producing more waste water with higher biological oxygen demand than both Bangladesh and World Bank standards. Focus group discussion and in-depth interviews with community members and health practitioners revealed that the perception of the community is that health problems are increasing as a result of industrial pollution of the wetlands that they traditionally use as a source of water to irrigate crops, for bathing and for fishing.

**Table 7. Median values of different parameters in water in seven locations of Mokesh Beel ecosystem in 2001.**

Parameter	Bangladesh Standard (mg/l)	Median value (mg/l)	Range (mg/l)
BOD	150	407	380-500
COD	200.0	960	350 – 1600
DO	4.5 - 8.0	1	0.6 - 1.2
TSS	100.0	195	115 – 427
Sulfide	2.0	3.1	1.6 - 10.2
Oil and grease	10.0	27	17 - 45

Research in the industries themselves identified potential alternative production options which can increase dye fixation by up to 70% and consequently save an average factory about US\$ 67,000 a year and significantly reduce repeat dyeing and effluent discharge. The studies also highlighted the need for more effluent treatment

facilities and better management of those that already exist. Effluent Treatment Plants are a legal requirement for factories approved after 1995, but in 2000 only two factories in the area had such plants and they were functioning below optimum. The project has worked with industries to advise on setting up treatment plants and one new one has been established and four more are under construction.

By late 2005 there were around 166 textile related industries (all are export oriented) in the area, compared with about 12 that existed when MACH started working there in 1999, so the pollution problem is worsening overall. This means that there is an immediate need to increase the rate of implementation of proposed pollution mitigation options if there is to be any reduction in pollution. Without this the efforts of the communities and MACH that have seen fish yields in the greater Turag-Bangshi area restored from about 60 kg/ha to about 300 kg/ha by 2004 are likely to be irreplaceably lost.

### **Sustainability and Policy Change**

Industrialization is not the only threat to the long term survival of fisheries and wetlands in Bangladesh. Locally and centrally those who once controlled or aspire to control water bodies to complement their social and political influence and to earn income, and who have been disempowered when community organizations have taken on wetland management, are a threat once project support and attention end. The sustainability of the resource base (the habitat), of fish catches, and of local institutions that have adopted good practices all remain to be observed in the long term. The pollution issue has demonstrated one strength of community organizations – in Kaliakoir the RMOs have spontaneously taken up local campaigns for cleaner surface water, and have linked with national advocacy groups.

In the long term there is a need for administrative and policy support to these systems. In MACH the Local Government Committees, now regularized as Upazila Fisheries Committees, have been vital. To strengthen their influence over enforcement of water quality standards, MACH has facilitated signing of an MOU between the concerned UFC and Department of Environment. In general the community organizations have been registered as legal entities, and have access to funds – revolving loan funds in the case of the FRUGs. For co-management and continued wetland restoration endowment funds have been left to provide an annual income for the UFCs, most of which will be disbursed as grants to RMOs for habitat restoration. Government orders establishing these are a necessary step, but equally important has been building the capacity of the community organizations to interact with government and speak up for their interests, and testing the operation of this system in the last two years.

Even so, these are only isolated examples of good practice among the more than 4 million ha of wetlands in Bangladesh. Therefore MACH has focused for sustainability also on influencing the adoption of its lessons and best practices in the policies, strategies and precedents of government. This will serve to strengthen long term co-management in the project sites, and enable more widespread adoption. MACH has focused on working with DOF as it developed its Inland Capture Fisheries Strategy, Action Plan and Programme. The concept and details of UFCs have been proposed by DOF to be established nationally for the purpose of coordinating co-management.

Establishing national wetland sanctuaries by taking them out of leasing has set a precedent for replication in other major wetlands of the country, and MACH is helping DOF and MOFL develop a proposal for Hail Haor to be designated as a “Ramsar Site” for its long term recognition and wise use. MACH is helping the newly established inland capture fisheries team within DOF to provide support for “graduated” water bodies and their community organizations. Dialogues are also underway with major textile manufacturer buyers and trade organizations with the objective of improving the management of textile mills and reducing pollution.

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